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Specification of Environmentally Significant Areas in the Denver Region

Denver Regional Council of Governments, CO

Prepared for

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Regional Growth and Development Plan

Specification of Environmentally Significant Areas in the Denver Region

Denver Regional Council of Governments

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This report includes specific criteria for the designation of environmentally significant areas in the Denver Region. Environmentally significant areas are land and water areas that exhibit valuable and unique physical characteristics which have an important effect and influence on the quality of life for a community or individual. For the purposes of this study, environmentally significant areas include environmental hazard areas, environmentally sensitive areas, natural resource areas, park, recreation and open space areas. The technical information and documentation contained in this report relate to the regional development policies on environmental protection set forth in the Regional Growth and Development Plan for the Denver Region. These regional development policies provide direction and guidance to growth and development within environmentally significant areas and distinguish between those areas which should be left undeveloped and those which can be developed with restrictions or closer management.

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IN THE DENVER REGION

October, 1977

Prepared by

Comprehensive Planning Office
Denver Regional Council of Governments

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PREFACE

This report has been prepared by the Denver Regional Council of Governments to provide technical back-up information for the regional development policies relating to environmental protection which are set forth in the Draft Regional Growth and Development Plan published in July, 1977.

The author wishes to express her appreciation to staffs of many local, state and federal agencies for their cooperation and assistance in providing information for this report. Special thanks are extended to staffs of the Colorado Geological Survey, Colorado State Forest Service, Colorado Division of Water Resources, Colorado Division of Wildlife, U.S. Geological Survey, U.S. Department of Agriculture Soil Conservation Service, U.S. Bureau of Mines, Urban Drainage and Flood Control District, and the county planning departments of Adams, Arapahoe, Boulder and Jefferson Counties.

This report was prepared by Gail M. Hill, environmental planner, under the supervision of David Howell in the DRCOG Comprehensive Planning Office.

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INTRODUCTION

The current restatement of the Regional Growth and Development Plan for the Denver Region includes the specification of environmentally significant areas. Environmentally significant areas relate directly to the location and pattern of future growth and development as well as to the general quality of life within the region. This report includes the technical information and documentation which relates to the regional development policies on environmental protection which are set forth in the Regional Growth and Development Plan. These regional development policies provide direction and guidance to growth and development within environmentally significant areas and distinguish between those areas which should be left undeveloped and those which can be developed with restrictions or closer management. The proposed environmental policies are based on reasonable and defensible premises and every effort has been made to incorporate existing state and local regulations within those policies.

This report includes specific criteria for the designation of environmentally significant areas in the Denver Region. Environmentally significant areas are land and water areas that exhibit valuable and unique physical characteristics which have an important effect and influence on the quality of life for a community or individual.

For the purposes of this study, environmentally significant areas include the following components:

Environmental hazard areas
Environmentally sensitive areas
Natural resource areas
Park, recreation and open space areas

Environmental hazard areas are those physical areas or regions of the earth's surface that are highly susceptible to an adverse impact by some natural occurrence so as to constitute a significant threat or danger to public health and safety or to property. Specific environmental hazards analyzed in this report include floodplains, wildfire hazard areas, landslides, subsidence hazard areas, shrink-swell soils and faults.

Environmentally sensitive areas are those physical areas which maintain a unique ecological balance such that interference by man and his activities will upset this balance and alter the ecosystem. These areas are easily upset, destroyed or altered by introduced development. Environmentally sensitive areas analyzed in this report include significant wildlife habitat areas.

Natural resource areas are those physical areas which are a source or supply of a naturally occurring physical element or raw material of benefit to man and his activities. These may include commercially beneficial depositions of sand, gravel, aggregates or minerals of benefit for structural or energy uses, or such resources as surface and aquifer water, or prime agricultural lands. Natural resource areas analyzed in this report include sand, gravel and aggregate deposits, coal resources, oil and natural gas fields, alluvial and bedrock aquifers, and prime agricultural soils.

Park, recreation, and open space areas are those land and water areas which are acquired, regulated or managed to protect the natural environment, provide recreational opportunities, and/or shape the pattern of urban development. Also included are areas of historical, cultural and archaeological significance.

It is important to note that even though certain areas have been classified under a single environmentally significant area component, many areas have the characteristics of several of the components. A good example of this is floodplains. Even though a floodplain is classified as an environmental hazard, it also functions as an environmentally sensitive area because of its unique function of filtering runoff and maintaining an interface between the terrestrial and aquatic environments. Hence, it is an area whose ecological balance can be easily upset by man's activities. A floodplain can also be classified as a natural resource area because the alluvial deposits associated with streams act as aquifers and are also valuable as a source of sand and gravel. In addition, a floodplain is often an existing park and recreation area or part of a proposed recreational and open space greenbelt. Finally, many historical settlements or camps were located along the shorelines of rivers or streams and consequently floodplains are often sites of historically or culturally significant places.

When considering any environmental element that is classified as an environmentally significant area, it is important to consider all of the interrelationships that exist between that singular element and all the other environmentally significant area components.

All of the environmental elements which have been designated as environmentally significant areas and discussed in this report have been mapped for the Five-County Denver Region. The environmental elements have been mapped on 7 1/2' U.S. Geological Survey (USGS) Quadrangle maps (Scale 1 inch = 2,000 feet). There are 90 USGS quadrangles which cover the Five-County Denver Region. With individual mapping of the 14 different environmental elements, the environmental mapping associated with this report is comprised of more than 600 maps.

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The USGS quadrangle maps at a scale of 1 inch = 2,000 feet (1:24,000) were chosen as the base for mapping the environmentally significant areas because:

(1) They provide a good base and one which is commonly used by many local, regional, state and federal agencies.
(2) There would be a great loss of detail at smaller scales.
(3) The USGS quads provide a better basis for accurate land measuring.
(4) These maps provide a better basis for continuous updating of the environmental information.
(5) These base maps provide a better means for the review and evaluation of future plans, programs and projects with environmentally significant areas.

The detailed mapped environmental information base on the USGS quadrangles (Scale 1 inch = 2,000 feet) is not practical for all presentation and display purposes. Consequently, regional maps of all the environmental elements have been prepared at a scale of 1 inch = 2 miles. These regional maps have been further reduced to the page-size maps at a scale of approximately 1 inch equals 12 miles which are included in this report.

The information on the various environmental characteristics of the Denver Region which is set forth in this report, and the associated environmental mapping represents the most up-to-date information that is available at this time. As additional studies are prepared which provide more data and information on any of the environmental elements included in this report, this report should be updated accordingly. As new mapping studies are prepared, the DRCOG environmental map file on the USGS quadrangles will be updated continuously to reflect such new mapped information. This environmental map file will eventually serve as a basis for the review of proposed plans, programs and projects with the Regional Growth and Development Plan.

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FLOODPLAINS

Criteria for Specification:

Those land areas that fall within the limits of the Intermediate Regional Flood Level (100 year flood) are designated as environmental hazard areas in the Denver Region.

Basis for Criteria:

The Intermediate Regional Flood is a flood having a one percent probability or an average frequency of occurrence on the order of once in 100 years although the flood may occur in any year. It is based on statistical analyses of stream flow records available for the watershed and analyses of rainfall and runoff characteristics in the "general region of the watershed".[1] Potential flood levels are statistically derived from a complex procedure of evaluation and analysis of all past flow records combined with synthetic determinations. A curve is then established showing the flows representative of a certain flood level. There are problems, however, because no long records of stream flow data exist for the Western states and what data that does exist is not uniform throughout the State. However, this existing data can be extrapolated for use.

There are basically two levels of potential floods for which some flood protection is provided throughout the nation. One is the Intermediate Regional Flood, commonly referred to as the 100 year flood, and the other is the Standard Project Flood. The Standard Project Flood is the flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. Peak discharges for these floods are generally about 40% to 60% of the Probable Maximum Floods for the same basins. Such floods, as used by the Corps of Engineers, are intended as practicable expressions of the degree of protection that should be sought in the design of flood control works, the failure of which might be disastrous. The Standard Project Flood is of a greater magnitude than the Intermediate Regional Flood and represents one with a reasonable upper limit of expected flooding. However, it is not the largest flood that may occur.

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[1] "Floodplain Information Volume IV, Denver Metropolitan Region, Colorado," U.S. Army Corps of Engineers, October 1968.

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The Intermediate Regional Flood level has been used as the criteria for floodplain designation as an environmental hazard area in the Denver Region because that flood level (100 year floodplain) has been almost universally accepted as a reasonable level for floodplain regulation. It has been adopted as the standard zone for regulatory purposes by the National Water Resources Council and the Department of Housing and Urban Development Federal Insurance Administration. The Colorado Water Conservation Board (CWCB) is the agency that officially designates floodplains in the State and they use the 100 year flood level. The Urban Drainage and Flood Control District (Denver Metropolitan Area) prepares floodplain maps and designs flood protection structures for the 100 year flood. In addition, the 100 year flood is designated for regulation in the State of Colorado 1041 program. The 100 year floodplain has been mapped in floodplain studies prepared by the United States Geological Survey (USGS), the Soil Conservation Service (SCS), the Bureau of Reclamation and the U.S. Army Corps of Engineers. The U.S. Army Corps of Engineers generally designs flood protection structures on river channels for the 100 year floodplain unless there is substantial evidence to indicate that additional design protection is necessary.

It basically becomes economically infeasible to build protective structures for floods of a much greater magnitude than the 100 year flood level. While it is conceivable that highly technical engineering practices and options are available to provide structural protection from more rare and devastating floods such as the 500 year flood, the costs of providing this protection would be so high that it could not be economically justified. It has been determined that the Intermediate Regional Floodplain will pass most of the damaging floods that might occur and consequently those areas are designated as environmentally significant. Development in the 100 year floodplain should not occur without appropriate safequards.

As indicated above, there are many agencies involved in floodplain regulation in the Denver Region. The U.S. Army Corps of Engineers has prepared floodplain studies for the major rivers and streams in the Denver Metropolitan Area. Included in these studies is a delineation of both the anticipated levels of a Standard Project Flood and an Intermediate Regional Flood. The U.S. Army Corps of Engineers uses these flood levels in designing flood control devices.

The U.S. Geological Survey (U.S.G.S.) is also involved in floodplain mapping. The U.S.G.S. is involved only in the technical aspects of mapping as they map the 100 year floodplain, and delineate "flood-prone" areas. Indicating "flood-prone" areas on a map uses approximate methods. However, the detailed floodplain studies which delineate the 100 year floodplain include precise measurements and actual field data. U.S.G.S. provides much of the mapping and technical data which is used for the administration of regulatory floodplain programs by other federal agencies such as the FIA (Federal Insurance Administration), and by such state agencies as the Colorado Water Conservation Board. The U.S.G.S. has provided a great deal of the floodplain mapping for the State of Colorado.

The U.S. Department of Agriculture, Soil Conservation Service (SCS), and the Bureau of Reclamation are other federal agencies which are also involved in the preparation of floodplain maps. These agencies, like the U.S.G.S., are only involved in the technical aspects of floodplain mapping and do not have any regulatory capabilities. The SCS is designated to prepare floodplain studies under PL-566, commonly referred to as the Small Watersheds Act. They are designated to study all streams with a flood hazard. The SCS has prepared floodplain maps for the FIA and the CWCB.

Another important aspect to consider in evaluating various floodplain maps is the basis for the 100 year floodplain. The U.S.G.S., in its technical mapping, delineates the 100 year floodplain on the basis of the existing land surface and existing development of the area. The Urban Drainage and Flood Control District of the Denver metropolitan area, will, however, indicate the 100 year floodplain based on existing channel conditions and also on foreseeable land uses in the floodplain area. To make this determination of foreseeable uses the Urban Drainage and Flood Control District will evaluate zoning plans for areas near rivers and streams and make a determination of the foreseeable development (usually for a five year period) based on the allowed uses and density limits in a particular zone. Assuming this amount of potential development near the river or stream, the Urban Drainage and Flood Control District will then calculate the 100 year floodplain. The Urban Drainage and Flood Control Board will then submit the completed 100 year floodplain mapping study to the Colorado Water Conservation Board for official approval.

The Colorado Water Conservation Board (CWCB) is the state agency which is responsible for flood control planning. It approves and officially designates floodplain levels before local governments can apply floodplain regulations to them. They will allow floodplain delineations based upon foreseeable uses to be included in floodplain regulations. The CWCB must also designate and approve studies delineating flood hazard areas before local governments can regulate floodplains. Flood hazard areas or flood prone areas are general areas of concern which have not had detailed studies to delineate the 100 year floodplain.

The Urban Drainage and Flood Control District and the U.S.G.S. are also involved in cooperative efforts to collect rainfall and runoff information for the Denver area. They operate a network of gauging stations on thirty drainage basins in the area and collect rainfall and runoff data for use in improving hydrologic models which are used to develop discharge figures for delineation of flood hazard areas and for the design of flood control facilities.

The Urban Drainage and Flood Control District's enabling legislation gave the District's Board of Directors the authority to adopt and enforce floodplain regulations in the District area. The Board of Directors of the District has, however, always felt that floodplain regulation could best be accomplished at the local level of government. Presently the local units of government are regulating their floodplains and so the District has not enforced its regulatory powers at this time.

One of the most significant agencies involved in the future use of floodplains is the Department of Housing and Urban Development Federal Insurance Administration. This agency administers the National Flood Insurance Program begun in 1968 and amended by the Flood Disaster Protection Act of 1973. This act makes flood insurance mandatory as a condition for any federally related financial assistance to communities or individuals wishing to acquire or refinance property or build within a flood hazard area. This act defines federally related financial assistance to include not only loans and grants from federal agencies such as the VA and FHA, but also, money provided through federally regulated or insured institutions such as banks, credit unions and savings and loan associations. In effect, this requirement includes virtually all mortgage and construction money. A community must have floodplain mapping and floodplain regulations in order to participate in the flood insurance program. Therefore, a community is pressed into developing floodplain regulations so that its citizens can obtain the mandatory floodplain insurance necessary to allow construction in a floodplain hazard area. The FIA generally only initiates mapping on streams where there is human habitation. This delineation of the 100 year floodplain is legally based on existing development rather than foreseeable development.

The FIA can and will suspend insurance coverage to individuals in a municipality if that municipality is not enforcing acceptable floodplain regulations. The minimum requirements of the floodplain regulation are that new construction or substantial improvement of existing homes in the floodplain must have the lowest level above the elevation of the 100 year flood and that ordinances must, at a minimum, prohibit the expansion of existing structures in the floodway and prohibit fill or encroachments in the floodway unless they are mitigated by offsetting stream improvements compensating for reductions in the carrying capacity.

All of the counties in the DRCOG region have some type of floodplain ordinance at this time. In addition, floodplain regulations are also in existence for most of the municipalities in the Denver Region. These ordinances presently meet the minimum FIA requirements for floodplain protection and, consequently, flood insurance is available in this region. The limitations and specific allowable uses within the floodplain areas do differ from municipality to municipality, however, with some municipalities following the minimum requirements and others providing for additional protection of their environmentally significant floodplains.

The 100 year floodplain has been categorized as an environmentally significant area primarily because it is an environmental hazard area, but it is also an environmentally sensitive area, a natural resource area, and oftentimes may also be the site of an existing or proposed park, recreation or open space area.

The 100 year floodplain is an environmental hazard area because of the obvious threat of damage from floods to human life and property in floodplain areas. Every year many people are killed, injured, left homeless, and caused immeasurable suffering and hardship because of flood damage. Millions of dollars in property damage results through flood damage.

Historically, the national policies for flood protection have been to construct protective works to lessen flooding. In fact, since 1936, federal agencies have spent over $25 billion on such projects as the construction of dams, levees and other flood works. While these measures have, in some cases, saved lives and prevented property damage, annual flood losses have risen until, by 1973, they cost the nation about $1.25 million.[2]

A large problem seems to be that rather than reducing flood damage the dams, channelization projects, dikes, levees and other structural measures have tended to lure more development into the floodplain. Such structural solutions to flooding problems seems to create a false sense of security among those whom they would protect, even though such structural systems are subject to structural and mechanical failure. Structural solutions also usually have detrimental ecological effects. They interfere with the normal cycles of renewal of bottomland soils. They can affect the biological productivity of a river as well as destroying the natural wetland habitat, which is so important for a variety of species of wildlife commonly found along and adjacent to the shorelines of rivers and streams. And very importantly, structural flood control measures effect the floodplains natural functions of recharging groundwater.

A floodplain is an environmentally sensitive area for a multitude of reasons. It acts as a filter to cleanse much of the runoff entering a stream; it provides habitat for many water-dependent species of animals and vegetation; it provides an area for soil enrichment when the adjacent stream or river overflows its banks, and most importantly it maintains an important interface and ecological balance between the aquatic and terrestrial environments.

Development in floodplain areas because of their sensitive characteristics, can have many harmful effects upon the water quality of the adjacent stream. Development along a stream will increase erosion due to the disruptive construction activities and removal of portions of the existing vegetative cover. Development in floodplain areas will also increase the amount of runoff because of the structures, paved roads and parking areas, which means less permeable areas for rain, etc. to soak into the ground. The results of the increased erosion and runoff will be increased sedimentation in the stream. This increased sedimentation can cause irregular flow and can choke a stream's connection with groundwater formations. Degraded water quality of stream resources means that the resource becomes less fit to provide quality water sources, quality water oriented recreational activities, quality habitats and pathways for many species of birds and animals and an overall less desirable element of the environment in which man, animal and plant live.

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[2] Source: Environmental Update on Water "Floodplain Management and the National Flood Insurance Program," League of Women Voters, Pub. #534, January 1975.

Depositions of sand and gravel, so vitally important to the construction industry, are generally found in the alluvial outwash depositions along streams and hence within the 100 year floodplain. Consequently, the floodplain is environmentally significant in terms of its function as a source of sand, gravel and aggragates. In addition, the alluvial depositions along streams oftentimes function as aquifers and aquifer recharge areas, and are consequently an important natural resource for storing and transmitting ground water.

Finally, floodplain areas are often the site of existing or proposed parks, open spaces or greenbelt areas. Early settlers often established camps or settlements along the shorelines of rivers, streams and lakes, and consequently a floodplain area often contains significant historical or cultural sites.

MAPPING STUDIES USED IN DESIGNATING FLOODPLAINS IN THE DENVER REGION

Urban Drainage and Flood Control District - Floodplain Information Maps
100 Year Floodplain
Scale: 1 inch = 1000 feet (1:12,000)
Maps for:

- Bear Creek
- Boulder Creek
- North Boulder Major Drainageways
- South Boulder Area Drainageways
- South Boulder Creek
- Cherry Creek
- Clear Creek
- Coon Creek
- Cottonwood Creek
- Big Dry Creek (Adams County)
- Little Dry Creek (Adams County)
- Little Dry Creek & Tributaries (Arapahoe County)
- Dutch Creek
- Goldsmith Gulch
- Lakewood Gulch
- Lena Gulch
- Leyden Creek
- Lilley Gulch
- McIntyre Gulch
- Niver Creek
- South Platte River
- Ralston Creek
- Sand Creek
- Sanderson Gulch
- Toll Gate, East Toll Gate, & West Toll Gate Creeks
- Van Bibber Creek
- Weir Gulch

FIA Flood Hazard Boundary Maps for Municipalities (Department of Housing and Urban Development - Federal Insurance Administration)

Scales vary on individual maps. Some are as detailed as 1 inch = 400 feet, whereas, others are as small as 1 inch = 2,000 feet. Range of Scales - 1:4,800; 1:6,000; 1:7,200; 1:9,600; 1:12,000; 1:24,000. Maps for the following communities:

Adams County

Bennett
Brighton
Federal Heights
Northglenn
Thornton
Westminster

Arapahoe County

Deer Trail
Strasburg*

Boulder County

Broomfield
Longmont
Louisville
Superior

Jefferson County

Buffalo Creek*
Evergreen*
Kittredge*

Adams County Floodplain Maps, prepared in Summer 1976, by Gingery Associates for HUD FIA mapping.
Detailed mapping for:

Box Elder Creek (southern portions)
Brantner Gulch
Comanche Creek (southern portions)
Second Creek
Third Creek
Todd Creek

Mapping of 100 Year Floodplain at a Scale of 1" = 2,000' (1:24,000)

East Bijou Creek
West Bijou Creek
Box Elder Creek

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* = Unincorporated Area.

Comanche Creek
First Creek
Kiowa Creek
Lost Creek
Muddy Creek
Wolf Creek

Arapahoe County 100 Year Floodplain Information - Flood Insurance Study for U.S. Department of Housing and Urban Development Federal Insurance Administration - Scale 1" = 2,000' - Set of four maps from Arapahoe County Planning Department.

Jefferson County Floodplain Map
Jefferson County Planning Department
Scale 1" = 1,000' (1:12,000)
Source: U.S. Army Corps of Engineers
Maps for:

T3S, R70W
T4S, R70W

City of Boulder
100 Year Floodplain Map
Revised March 1976
Scale 1" = 1,000' (1:12,000)

Boulder County Geotechnical Maps
They indicate floodplain areas, and areas with potential high risk hazard from flash flooding in mountain canyons.
Scale 1" = 2,000' (1:24,000)

Boulder County Floodplain Maps
Boulder County Department of Development
Area Subject to Floodplain Regulations
Scale 1" = 500' (1:6,000)
Maps for:

St. Vrain Creek
Left Hand Creek

City of Longmont Floodplain Map
St. Vrain Creek
Scale 1" = 400' (1:4,800)

100 Year Floodplain
Golden Planning Department
by U.S. Army Corps of Engineers
Scale 1:12,000
Maps for:

Clear Creek
Tucker Gulch

100 Year Floodplain
Lakewood Planning Department
Scale 1:12,000

Flood Hazard Analyses - Coal Creek and Rock Creek, Boulder and Weld Counties, by U.S. Department of Agriculture Soil Conservation Service

Maps of Coal Creek at scales of 1:4,800 and 1:50,000
Maps of Rock Creek at scales of 1:4,800 and 1:50,000

Preliminary Map of 100 Year Floodplain
Stream Studied by Approximate Method
U.S. Geological Survey
Scale 1" = 500' (1:6,000)
Maps for the following streams in Jefferson County:

Bear Creek
Beaver Brook
Beaver Creek
Blue Creek
Brush Creek
Buffalo Creek
Buffalo Creek (Lower Jeffco)
Casto Creek
Clear Creek
Coal Creek
Cold Spring Gulch
Cub Creek
Deer Creek
N. Fork Deer Creek
S. Fork Deer Creek
Elk Creek
Giant Gulch
Guy Gulch
Kennedy Gulch
Kerr Gulch
Lans Gulch
Last Resort Creek
Leyden Gulch
Little Cub Creek
Mt. Vernon Creek
Myers Gulch
Pine Gulch
Ralston Creek
W. Resort Creek
S. Platte River
N. Fork S. Platte
Swede Gulch
Switzers Gulch
Tucker Gulch
N. Turkey Creek
S. Turkey Creek
Van Bibber Creek

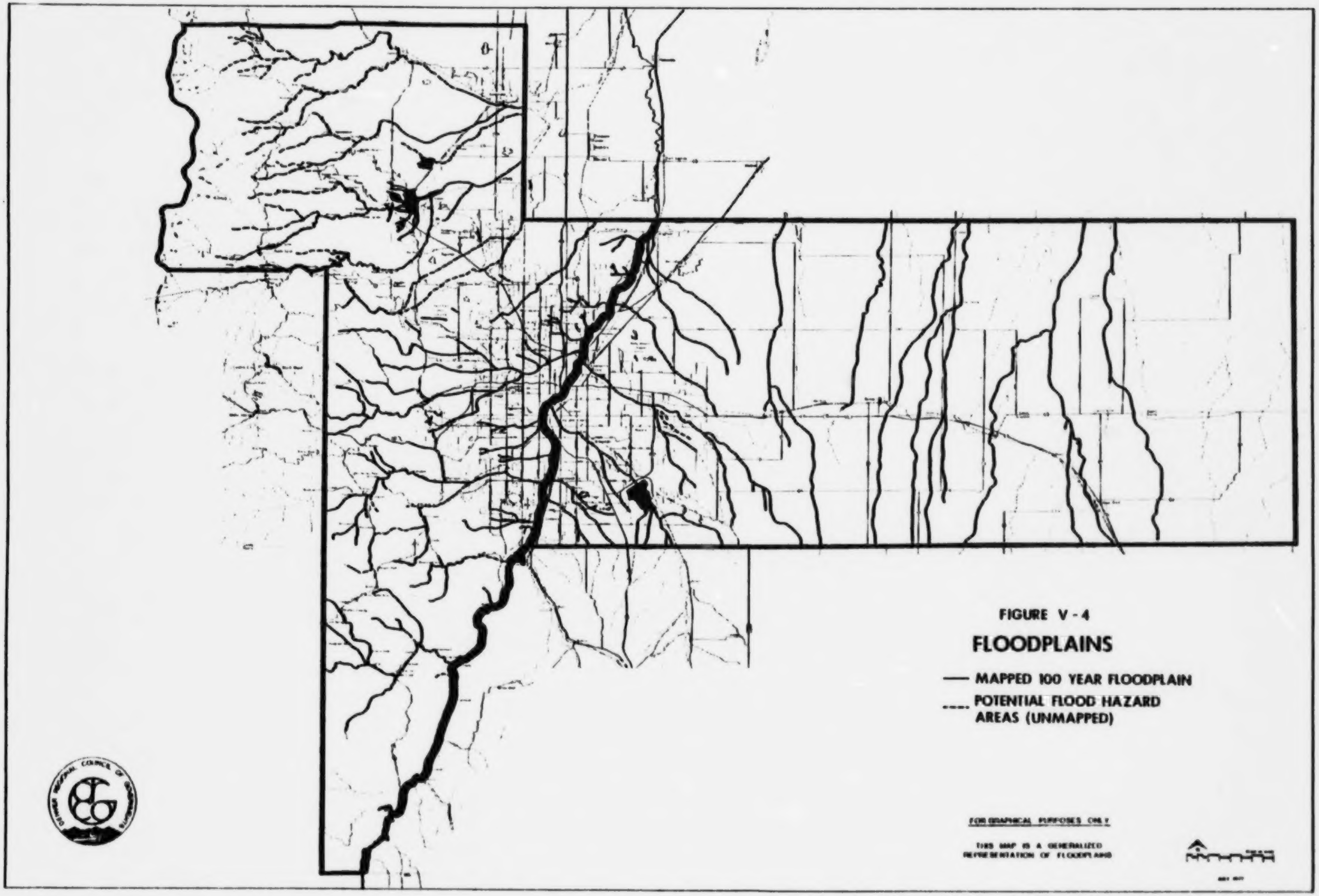

FIGURE V - 4

FLOODPLAINS

— MAPPED 100 YEAR FLOODPLAIN
---- POTENTIAL FLOOD HAZARD AREAS (UNMAPPED)
FOR GRAPHICAL PURPOSES ONLY
THIS MAP IS A GENERALIZED REPRESENTATION OF FLOODPLAINS

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City of Littleton, Slaughterhouse Gulch, Master Plan, Major Drainage Way Planning, Report and Drawings, Frasier & Gingery, Inc., Consulting Engineers, May 1974.

Department of Public Works, City and Co. of Denver, Master Planning for Storm Runoff for New North/South Runway and Environs, Stapleton International Airport, Denver, Co., Master Plan Report Volume II, Wright-McLaughlin Engineers, Engineering Consultants, November 1969.

DRCOG, Pilot Planning Study for Area Wide Storm Drainage Planning, Proposed Wonderland Creek Drainage Way Near 33rd Street, Boulder, Co., Volume II, North Boulder Major Drainage Ways Drawings, Wright-McLaughlin Engineers, Engineering Consultants, April 1969.

Flood Hazard Analyses - Coal Creek and Rock Creek, Boulder and Weld Counties, Colorado, prepared by the U.S. Department of Agriculture Soil Conservation Service, Denver, Colorado in cooperation with the Colorado Water Conservation Board, Urban Drainage and Flood Control District, Coal Creek Water Users Association, Boulder County, and Weld County, October 1976.

FLOODPLAIN REFERENCES

Journal of the American Institute of Planners (AIP) Volume 42, Number 3, July 1976, "The National Flood Insurance Program: Some Midstream Perspectives" by Rutherford H. Platt, pgs. 303 to 313.

"Criteria and Procedures for Flood Hazard Mapping" - prepared by the Colorado Water Conservation Board to meet mandates of H.B. 1041; August 29, 1974.

This publication didn't present many specifics for identification. It indicated that floodplain mapping is a highly technical process that takes a good deal of time and that communities should prioritize their needs for floodplain mapping.

"Model Land Use Regulations - Chapter 6 - Floodplain Regulations" - Colorado Land Use Commission.

Performance Controls for Sensitive Lands, A Practical Guide for Administrators by Charles Thurow, William Toner & Duncan Erley, ASPO Planning Advisory Service Report #307, 308.

This report includes a very good section on protection of streams and creeks. It discusses the valuable functions of streams and creeks and how infringement of development can alter these functions. It also discusses modes of floodplain regulation.

"Development Criteria to Keep Impact Within Acceptable Levels," Technical Memorandum 3-2, Resource Planning Associates, Inc., March 19, 1976.

This memorandum includes a discussion of the significance of floodplains as well as suggestions for policies to protect them.

"Activity Summary of the Urban Drainage and Flood Control District," March 1976.

Environmental Update on Water, Pub. #534, January 1975, "Floodplain Management and the National Flood Insurance Program" prepared by the League of Women Voters.

"Water Over the Bridge - Dollars and Sense on the Floodplain" staff report from the November/December 1975 Sierra Club Bulletin.

Manual for Estimating Flood Characteristics of Natural-Flow Streams in Colorado, Colorado Water Conservation Board, Colorado Department of Natural Resources, Technical Manual #1, prepared in cooperation with the U. S. Geological Survey, 1976.

"Mountain Land Planning" by Dennis L. Lynch and Standish R. Broome.

This report has a good discussion of natural hazards including flood hazards.

Regulations for Floodplains - American Society of Planning Officials Planning Advisory Service Report #277, February 1972, by Jon A. Kusler and Thomas M. Lee.

This report is a good manual for floodplain regulations and a good legal reference.

Regulation of Flood Hazard Areas to Reduce Flood Losses, prepared by U.S. Water Resources Council; 1969; 2 Volumes.

This report is a complete legal review of case histories of land use and floodplain regulation. It also includes discussions on subdivision regulation for flood hazard areas, coastal regulations to reduce flood losses and copies of draft local floodplain regulation ordinances.

Federal Register - Part II: Department of Housing and Urban Development, Federal Insurance Administration, National Flood Insurance Program, Tuesday, October 26, 1976.

"What Colorado Resident's Should Know About Flood Insurance," pamphlet about the availability and cost of federally-subsidized flood insurance.

FLOODPLAIN MAPS

Urban Drainage and Flood Control District - Floodplain Information
    100 Year Floodplain
    Scale: 1 inch = 1000 feet (1:12,000)
    Maps for:

- Bates Lake
- Bear Creek
- Boulder Creek
- North Boulder Major Drainageways
- South Boulder Area Drainageways
- South Boulder Creek
- Cherry Creek
- Clear Creek
- Coon Creek
- Cottonwood Creek
- Dry Creek
- Big Dry Creek (Adams Co.)
- Big Dry Creek (Arapahoe Co.)
- Little Dry Creek (Adams Co.)
- Little Dry Creek & Tributaries (Arapahoe Co.)
- Dutch Creek
- Goldsmith Gulch
- Grange Hall Creek
- Hidden Lake
- Lakewood Gulch
- Lena Gulch
- Leyden Creek
- Lilley Gulch
- Lone Tree Creek
- McIntyre Gulch
- Mt. Vernon Creek
- Murphy Creek
- Niver Creek
- Piney Creek
- South Platte River
- Ralston Creek
- Sand Creek
- Sanderson Gulch
- Second Creek
- Third Creek
- Toll Gate, East Toll Gate, & West Toll Gate Creeks
- Van Bibber Creek
- Weir Gulch

FIA Flood Hazard Boundary Maps for Municipalities (Department of Housing and Urban Development - Federal Insurance Administration)

Scales vary on individual maps. Some are as detailed as 1 inch = 400 feet, whereas, others are as small as 1 inch = 2000 feet. Range of Scales - 1:4,800; 1:6,000; 1:7,200; 1:9,600; 1:12,000; 1:24,000. Maps for the following communities:

Jefferson County

Arvada
Buffalo Creek*
Edgewater
Evergreen*
Golden
Kittredge*
Lakewood
Morrison
Pine*
Pleasant View*
Wheat Ridge

Arapahoe County

Aurora
Byers*
Cherry Hills Village
Columbine Valley
Deer Treail
Englewood
Greenwood Village
Littleton
Normandy Parkway Area*
Sheridan
Strasburg*
Suburban Denver*
Valley Club Acres*

Adams County

Arvada
Bennett
Brighton
Commerce City
Federal Heights
Northglenn
Thornton
Westminster

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* = Unincorporated Area.

Boulder County

Boulder
Broomfield
Erie
Lafayette
Longmont
Louisville
Lyons
Superior

Denver County

City and County of Denver

Douglas County

Blakeland*
Castle Rock
East & West Cherry Creek Areas*
Franktown*
Grandview Estates*
Greenland*
Larkspur*
Littleton
Livengood Hills*
Louviers and Plum Creek Areas*
Parker*
Platte River Area (Deckers, Snow Water Springs, Swayback Ranch,
   Night Hawk, Twin Cedars, Grandview Resort)*
Sedalia*
Willow Creek Area (Noma)*

Gilpin County

Black Hawk
Central City

Clear Creek County

Idaho Springs

Adams County Floodplains (from Adams County Planning Department)
   H.B. 1041, Technical Indentification Map
   Scale 1 inch = 4000 feet

Adams County Floodplains Maps (Preliminary), prepared in Summer 1976 by Gingery Associates for HUD FIA mapping. Detailed mapping for:

Big Dry Creek
Box Elder Creek (southern portions)
Brantner Gulch
Clear Creek
Comanche Creek (southern portions)
Grange Hall Creek
Hidden Lake
Niver Creek
Northfield Creek
South Platte River
Second Creek
Third Creek
Todd Creek

Mapping of 100 Year Floodplain at a Scale of 1" = 2000' (1:24,000)

East Bijou Creek
West Bijou Creek
Box Elder Creek
Comanche Creek
First Creek
Kiowa Creek
Lost Creek
Muddy Creek
Wolf Creek

Arapahoe County 100 Year Floodplain Information - Flood Insurance Study for U.S. Department of Housing and Urban Development Federal Insurance Administration - Scale 1" = 2000' - Set of 4 maps from Arapahoe County Planning Department.

Jefferson County Floodplain Map
Jefferson County Planning Department
Scale 1 inch - 1000 feet
Source: U.S. Army Corps of Engineers
Maps for:
T2S, R69W
T3S, R69W
T4S, R69W
T5S, R69W
T6S, R69W
T3S, R70W
T4S, R70W
T5S, R70W

City of Aurora
Flood Hazard Boundaries
Prepared by FIA, July 1974

City of Aurora
Sand Creek Master Plan Map

City of Boulder
100 Year Floodplain Map
Revised March 1976
Scale 1" = 1000'

Boulder County Geotechnical Maps
They indicate floodplain areas.
Scale 1" = 2000'

Map Showing Flood Prone Areas, 1975
U.S.G.S. Scale 1:100,000
Greater Denver Area
Boulder Area

Map Showing Areas of Past Flooding in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry
U.S.G.S. 1972, Map I-770-B, Scale 1:24,000.

Index Map showing which areas in Colorado have floodplain maps or reports, which areas have floodplain studies in progress, and which areas have no floodplain studies. The index also shows which quads have flood-prone mapping done.
U.S.G.S. January 1, 1975

Boulder County Floodplain Maps
Boulder County Department of Development
Area Subject to Floodplain Regulations
Scale 1" = 500'
Maps for:

St. Vrain Creek
Left Hand Creek
Boulder Creek
South Boulder Creek

City of Longmont Floodplain Map
St. Vrain Creek
Scale 1"= 400'

Preliminary Map of 100 Year Floodplain
Stream Studied by Approximate Method
U.S. Geological Survey
Scale 1" = 500'
Maps for the following streams in Jefferson County:

Bear Creek
Beaver Brook
Beaver Creek
S. Beaver Creek
Big Dry Creek
Blue Creek
Brush Creek
Buffalo Creek
Buffalo Creek (Lower Jeffco)
Casto Creek
Clear Creek
Coal Creek
Cold Spring Gulch
Cub Creek
Deer Creek
N. Fork Deer Creek
S. Fork Deer Creek
Elk Creek
Grant Gulch
Guy Gulch
Kennedy Gulch
Kerr Gulch
Kinney Creek
Lans Gulch
Last Resort Creek
Lena Gulch Tributary
Leyden Gulch
Little Cub Creek
Mt. Vernon Creek
Myers Gulch
Pine Gulch
Ralston Creek
W. Resort Creek
S. Platte River
N. Fork S. Platte
Swede Gulch
Switzers Gulch
Tucker Gulch
N. Turkey Creek
S. Turkey Creek
Van Bibber Creek
Woman Creek

PERSONAL CONTACTS FOR FLOODPLAIN INFORMATION

Ruby Flynn or Ruth Fuller
CNA Insurance Company
861-0561
- Distributes FIA floodplain maps

Bill DeGroot
Urban Drainage and Flood Control District
2480 West 26th Avenue
Suite 156-B
Denver, Colorado 80211
455-6277
- Distributes maps of the 100 year floodplain in the metropolitan area which are the most up-to-date version of floodplains officially designated by the Colorado Water Conservation Board, Scale: 1 inch = 1000 feet.

Rulon Christiansen
U.S.G.S.
Federal Center
Building 53 Room E2312A
Denver, Colorado 80225
234-3815
- Has prepared preliminary floodplain mapping for southern and western Jefferson County.

Tom Stone
Gingery Associates, Inc.
761-4860
- Consultants who did floodplain mapping for Adams County and Arapahoe County

Jerry Olson
FIA - Federal Insurance Administration
Federal Building
1961 Stout Street
Denver, Colorado 80202
837-2347

John Velehradsky
Chief of Planning Division of U. S. Army Corps of Engineers
Omaha, Nebraska
(402) 221-4575

Jim Biesecker
District Hydrologist
U.S.G.S.
234-3815
- He has information on all USGS floodplain mapping.

Gail Seeburger
Adams County Planner
450 South 4th Street
Brighton, Co. 80601
659-2120
- She has floodplain information for Adams County.

Mr. Van Camp
Colorado Water Conservation Board
892-3441

Pete Fogg
Boulder County Planner
P. O. Box 471
Boulder, Colorado 80302
441-3390
- He has information on floodplains for Boulder County.

Tom Stamn
Arapahoe County Planner
5606 South Court Place
Littleton, Colorado 80120
794-9211

Donna Paschke
Land Use Administrator - Jefferson County
and
Bill Blackburn
Jefferson County Planner
1700 Arapahoe
Golden, Colorado 80419
279-6511
- They both have floodplain information for Jefferson County.

WILDFIRE HAZARD AREAS

Criteria for Specification: The criteria for designation of wildfire hazard areas in the Denver Region are based upon varying definitions of wildfire hazards within Jefferson County and Boulder County. The criteria for these wildfire hazard areas in each county are as follows:[1]

1. Jefferson County

Wildfire hazard areas in Jefferson County are those areas where the chances of wildfire are classified as "severe" or "moderate."

A. Moderate Wildfire Hazard

Wildfire hazard areas can have several combinations of fuel and slope. One type of moderate wildfire hazard area has a timber density of 35-55% conifer crown coverage with a slope of less than 30%. The fuel in this hazard area includes, but is not limited to, fuels of medium density conifer stands with a surface fuel mainly of herbage and litter and some patches of reproduction and deadwood. Another composition of a moderate wildfire hazard area has a density of less than 35% conifer crown coverage with fuels including, but not limited to, grasses and brush other than oak, sage or snowbrush ceanothus, aspen, cottonwood, willow, open conifer stands, deadwood contacting the ground and the presence of either slash, ladder fuels, or a slope factor.

B. Severe Wildfire Hazard

(1) A severe brush wildfire hazard is composed of an area with a timber density of less than 30% conifer crown coverage with a nearly continuous coverage of high brush or conifer saplings. The fuel is dense to moderately dense flammable vegetation over two feet high, including Gamble Oak (in fall), big sagebrush, conifer reproduction, abundant litter and/or herbaceous fuels and the possible presence of scattered conifer stands.

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[1] "Wildfire Hazard Area Regulations," Colorado Land Use Commission Model Land Use Regulations, Chapter 5.

Reproduced from best available copy.

(2) A severe tree wildfire hazard may be any of the following compositions:

a. Timber density greater than 55% conifer crown coverage.

b. Timber density of 50-55% with a slope factor of 30% or greater including, but not limited to, fuels of dense conifer stands with any surface fuels.

c. Timber density of 35-55% conifer crown coverage including, but not limited to, fuels of medium density of conifer reproduction and deadwood with a slope factor of less than 30% in the presence of slash or ladder fuels.

d. Timber density of 35-55% conifer crown coverage including, but not limited to, fuels of medium density of conifer reproduction and deadwood with a slope factor of greater than 30% when slash or ladder fuels are not present.

e. Areas of severe slash with or without crown cover, regardless of slope.

2. Boulder County

Wildfire hazard areas in Boulder County are those areas where the chances of a wildfire are classified as "severe" or "moderate," based upon ecosystem classifications, slope, aspect, conifer crown coverage, vegetation type and potential ignition sources including urban development. The following ecosystems, with some variations for the above mentioned characteristics, are designated as wildfire hazard areas:

Severe Wildfire Hazard

Douglas Fir ecosystem
Lodgepole Pine ecosystem
Mixed Conifer ecosystem
Ponderosa Pine ecosystem

Moderate Wildfire Hazard

Limber-Bristlecone Pine ecosystem
Mountain Grasslands ecosystem
Sagebrush ecosystem

Basis for Criteria: A wildfire is created by the interaction of several components. These components include:

1. An ignition source which starts a fire such as lightning or purposeful or accidential causes by man.

2. Weather factors such as wind, temperature and moisture, or lack of moisture which allow a fire to burn and spread. The air, of course, provides oxygen which enables the fire to sustain itself.

3. Fuel conditions which provide material for the fire to burn such as trees, shrubs, and grasses.

4. Topography which helps spread the fire to other areas and which hinders fire control efforts.

Dense vegetation creates a very high wildfire hazard. Dense stands of conifer trees transmit the fire from the forest floor into the tree canopy and the tree crown. A crown fire is the most destructive fire type because it spreads so rapidly to the interlocking crowns of adjacent trees and because it is so very intense. Slash piles (vegetative debris left after cutting or clearing operations in forest or brush areas) greatly add to a wildfire hazard.

The location of development and construction techniques are often responsible for the creation of an unusually high fire danger because of introduced ignition sources. "Fire chimney" areas are highly susceptible to wildfires. These areas are ravines characterized by steep slopes (greater than 30%) and dense vegetation. In the ravines, winds are frequently stronger than they are on the ridges, and as a result, the ravines function as a chimney by drawing the fire rapidly upslope, sometimes too fast for any person or animal living in the ravine to escape its destructive force.

Separate criteria for wildfire hazard areas in Boulder County and Jefferson County have been used for designation of wildfire hazard areas within the Denver Region. These criteria have been based on the special and unique characteristics of the different areas and represent the best criteria and mapping that is currently available. In Jefferson County, the criteria are based upon guidelines and wildfire hazard mapping of the

Colorado State Forest Service (CSFS). These wildfire ratings were set forth in 1974 and adopted by the Colorado Land Use Commission in March, 1976. The mapping of wildfire hazard areas was completed by the Colorado State Forest Service in 1972 as an indicator and not a specific boundary of wildfire hazard areas. The mapping accuracy was to a five acre resolution. Wildfire hazard severity ratings, as established by the Colorado State Forest Service, are based mainly upon fuel availability and type, and topographic features of slope and aspect. The wildfire hazard severity rating will change to reflect these variables.

There are, however, some problems with these CSFS wildfire hazard area maps. The Colorado State Forest Service (CSFS) prepared the first Wildfire Hazard maps in 1970. Jefferson County was the first county to be mapped and the mapping technique was not yet refined. The base aerial photography used for the vegetative cover interpretations to prepare the maps was from 1956. Changes in the ecosystems over the past 20 years, including some related to introduced development, may have substantially changed the classifications.

The Jefferson County Planning Department is presently in the process of refining the wildfire hazard mapping within the county. They have prepared a wildfire algorithm including 14 different vegetation units and 6 varying slope units to produce wildfire value ratings from 0-9. Each of these wildfire value ratings are described by vegetation unit, slope, fire behavior and land use capabilities. This system, which involves computer mapping, is not yet complete for designating wildfire hazard areas in Jefferson County, and until it is, the CSFS Wildfire Hazard maps should be used for planning purposes.

The wildfire hazard mapping used in Boulder County is a revision of the CSFS Wildfire Hazard Area Mapping. In late 1974, the Colorado State Forest Service prepared a guide for planners and landowners in Colorado involved in environmental planning in the foothills and mountains.[1] This report classified the natural environment into 17 different ecosystems, and an indication of potential wildfire hazard problems was developed for each ecosystem. These wildfire problem indicators are based not only on fuel and slope, but also on potential ignition sources. The wildfire hazard potential problem indicator for ecosystems classifies wildfire hazard into the following categories:

Problem May be Crucial
Problem Very Likely

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[1] An Ecosystem Guide for Mountain Land Planning, Dennis L. Lynch, Colorado State Forest Service, Colorado State University.

Exercise Caution
Problem Usually Limited

Table 1 includes a listing of the 17 ecosystems, their elevations, major vegetative composition and an indication of probable wildfire hazard problems.

The Boulder County Planning Department staff has modified the CSFS Wildfire Hazard Area Mapping of 1972 to include the ecosystem wildfire hazard indication system. In addition, other factors such as mountain road traffic, off-road vehicle traffic, areas of pine beetle kill, and urban settlement were taken into consideration in the designation and mapping of wildfire hazard areas for Boulder County. The original CSFS wildfire hazard area maps were based on 1972 infrared aerial photos. Due to the effect of the pine beetle and other factors, the biological character of some of the vegetation has changed significantly since 1972. In addition, the number of tourists traveling mountain roads and the number of off-road vehicles using the area have increased very significantly in recent years. These factors, as well as a significant introduction of urban development, are all considered as potential ignition sources, thus increasing the potential risk of a wildfire.

The Boulder County Planning Department staff has prepared their current wildfire hazard maps from 1975 color aerial photography and with technical assistance from the CSFS regarding eco-mapping techniques. The revised Boulder County Wildfire Mapping was completed in May, 1976 and reflects fire hazard based upon slope, aspect, fuel availability, conifer crown coverage, ecosystem type, mountain road traffic, off-road vehicle traffic, areas of beetle kill and urban settlement.

Potential wildfire areas also exist in the plains, however, the severity of wildfire in the plains is much less than that of a wildfire in the mountains and consequently these areas have not been designated as wildfire hazard areas in the Denver Region. Both the Adams County and Arapahoe County Planning Departments have prepared wildfire hazard area maps. Wildfire hazard areas for both Adams and Arapahoe Counties were identified with the technical assistance of Colorado State Forest Service (CSFS) staff and include areas of tall grasslands. In Adams County, the areas identified as potential wildfire hazard areas are vegetated areas usually associated with riparian habitats. No specific universal criteria exists for identifying wildfire hazards in the plains. The identified areas were selected on the basis of the mature height of grasses and weeds after a field reconnaissance of the area. These identifications are preliminary and very general and function mainly as an indicator of areas of potential tall grass wildfire hazard rather than as a specific wildfire indicator for use as a planning tool. It is important to emphasize that the amount and significance of fire danger in the plains is not nearly as high as in the mountains. Because the plains fire hazard is of much lesser significance than the mountain's fire hazard, the CSFS (in April, 1976) prepared exemption letters for 22 plains counties, exempting them from the wildfire hazard identification requirements of HB 1041.

As of this date, the mapping and rating of wildfire hazard areas in the counties in the Denver Region, based upon guidelines of the Colorado State Forest Service, is the best mapping and rating system that is available. However, continuing refinement of wildfire mapping techniques and criteria is an important activity of the State of Colorado and U.S. Forest Services. A new National Fire Danger Rating System has been developed and is being refined by additional research by the U.S. Forest Service. As these new methodologies and more refined fire hazard rating techniques and data become available, the wildfire hazard areas delineated in the DRCOG Regional Growth and Development Plan should be updated accordingly.

A wildfire hazard area is an environmental hazard area because it poses a serious threat of damage to human life and property from the occurrence of a wildfire. The forests along the mountainsides in Colorado exhibit evidence that fire has been a natural and very powerful part of the forested environment for a very long time. Wildfires can and do occur frequently in mountain areas and they can spread at an amazing speed. Homes, property, valuable timber and other natural resources, wildlife and humans are often destroyed before the fire can be contained.

Hillsides of 30% slope or greater will cause a fire to spread two times as fast as on level ground. In addition, fire fighting efforts are greatly hindered or made nearly impossible on steep slopes and in some forested areas. These physical limitations compound the severity of the wildfire hazard.

Because of high burning intensities, increased fire suppression difficulties, and the subsequent risks to public health, safety and property, identified wildfire hazard areas warrant close scrutiny, analysis and field inspection for any proposed developments or zoning.

TABLE I

Ecosystems - Mountain Wildfire Hazard Problem Indicator

ECOSYSTEM	ELEVATION RANGE	DOMINANT VEGETATION	WILDFIRE HAZARD PROBLEM INDICATOR
Alpine	11,000-12,000 Feet	dwarfed, gnarled trees grasses sedges forbs small, prostrate shrubs	Problem Usually Limited
Aquatic		aquatic vegetation	Problem Usually Limited
Aspen	7,000-10,000 Feet	aspen trees* (greater than 50% of forest cover) grasses forbs small trees & shrubs	Problem Usually Limited
Bog		sedges rushes willows	Problem Usually Limited
Douglas Fir	6,000-10,500 Feet	Douglas fir trees* (greater than 50% of forest cover) ponderosa pine aspen limber pine Englemann spruce small shrubs forbs grasses	Problem May Be Crucial
Greasewood-Saltbrush		greasewood* saltbrush* rabbitbrush sparse grasses sparse forbs	Problem Usually Limited

TABLE I - Continued

ECOSYSTEM	ELEVATION RANGE	DOMINANT VEGETATION	WILDFIRE HAZARD PROBLEM INDICATOR
Limber-Bristlecone Pine	7,500-11,500 Feet	limber pine* bristlecone pine* Englemann spruce subalpine fir forbs grasses	Exercise Caution
Lodgepole Pine		lodgepole pine* (greater than 50% of forest cover) Vaccinium shrub buffaloberry elk sedge	Problem May be Crucial
Meadow		grasses* sedges* forbs* sagebrush cinquefoil willow	Problem Usually Limited
Mixed Conifer	6,000-10,000 Feet	Douglas fir ponderosa pine white fir Englemann spruce limber pine aspen blue spruce corkbark fir	Problem May be Crucial
Mountain Grasslands		grasses* forbs* shrubs	Exercise Caution
Mountain Shrub		oakbrush* mountain mahogany* sumac* chokecherry* bitterbrush* rabbitbrush* forbs grasses sagebrush	Problem Very Likely

ECOSYSTEM	ELEVATION RANGE	DOMINANT VEGETATION	WILDFIRE HAZARD PROBLEM INDICATOR
Pinon-Juniper		pinon pine* juniper* shrubs forbs grasses	Problem Very Likely
Ponderosa Pine	5,000-9,000 Feet	ponderosa pine* (greater than 50% of forest cover) Douglas fir white fir limber pine aspen shrubs forbs grasses	Problem May be Crucial **
Riparian		willow cottonwoods alder aspen blue spruce rushes sedges forbs	Problem Usually Limited
Sagebrush		sagebrush* rabbitbrush bitterbrush saltbrush grasses forbs	Exercise Caution

TABLE I - Continued

ECOSYSTEM	ELEVATION RANGE	DOMINANT VEGETATION	WILDFIRE HAZARD PROBLEM INDICATOR
Spruce-Fir	8,000-11,500 Feet	Englemann spruce* subalpine fir* Douglas fir limber pine aspen blue spruce lodgepole pine brustlecone pine shrubs forbs	Problem Very Likely

SOURCE: An Ecosystem Guide for Mountain Land Planning, Level 1, by Dennis Lynch, Colorado State Forest Service, Colorado State University

* Dominant species

** The ponderosa pine in some areas may be exceedingly susceptible to wildfire because of its dried out condition caused by extensive damage by the pine beetle.

MAPPING STUDIES USED IN DESIGNATING WILDFIRE HAZARD AREAS IN THE DENVER REGION

Wildfire Hazard Area Maps
Colorado State Forest Service, 1973
Scale 1:24,000
Maps for the following U.S.G.S. quadrangles:

- Conifer
- Evergreen
- Indian Hills
- Morrison
- Pine
- Platte Canyon
- Ralston Buttes

Boulder County Wildfire Hazard Area Maps
Boulder County Planning Department
Scale 1:24,000
Maps for the following U.S.G.S. quadrangles:

- Allens Park
- Boulder
- East Portal
- Eldorado Springs
- Gold Hill
- Isolation Peak
- Lyons
- Monarch Lake
- Nederland
- Raymond
- Tungsten
- Ward

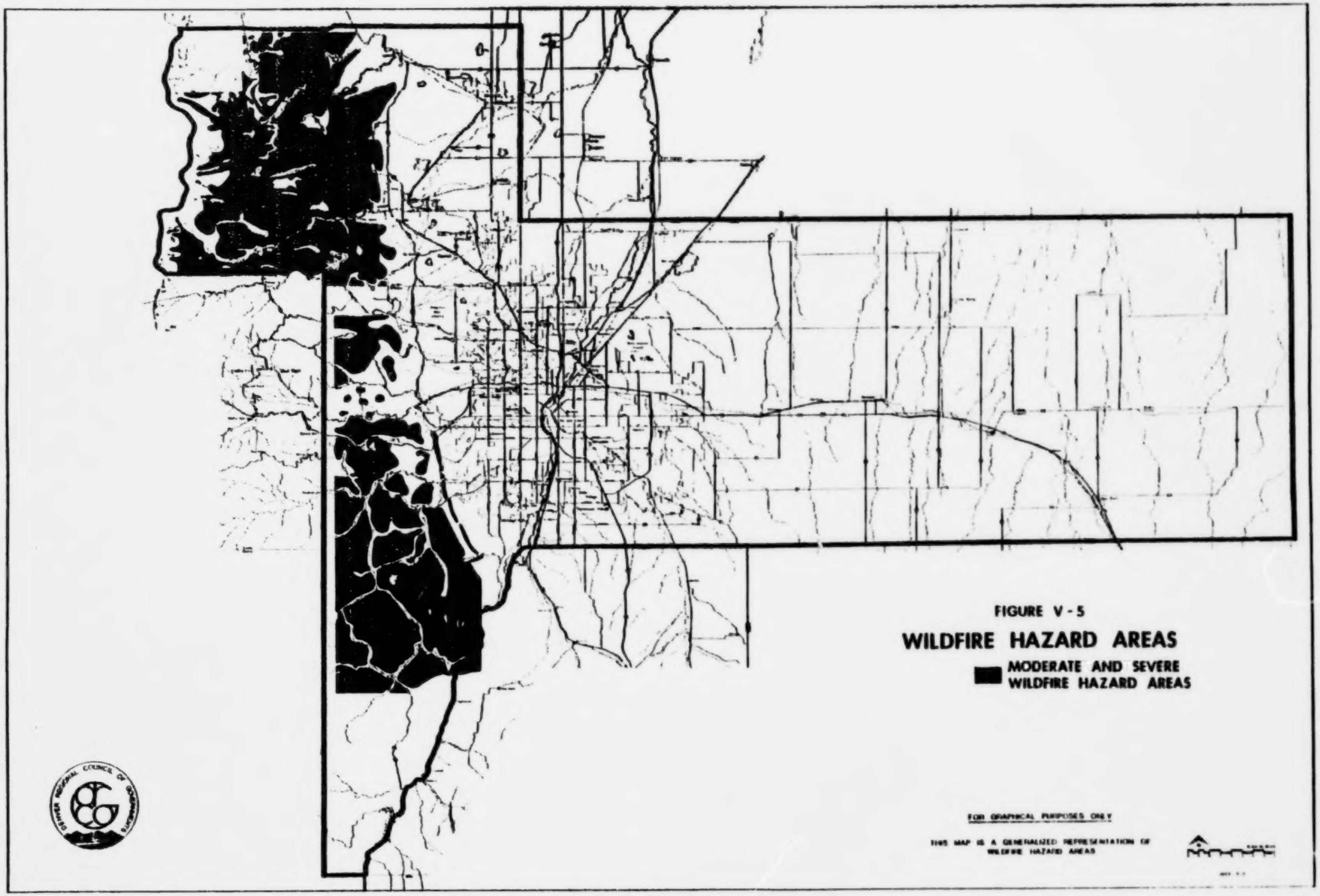
DENVER REGIONAL COUNCIL OF GOVERNMENTS

FIGURE V-5

WILDFIRE HAZARD AREAS

■ MODERATE AND SEVERE WILDFIRE HAZARD AREAS

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF WILDFIRE HAZARD AREAS

BIBLIOGRAPHY FOR WILDFIRE HAZARD AREAS

Sources Available at DRCOG

WILDFIRE HAZARD REFERENCES

"Wildfire Hazards: Guidelines for Their Prevention in Subdivisions and Developments", by the Colorado State Forest Service, Colorado State University, April 1973.

"Guidelines and Criteria for Wildfire Hazard Areas"
Includes:
Guidelines for Administration
Guidelines for Designation
Safety Guidelines and Standards
Model Wildfire Hazard Area Control Regulations
September 1974
by the Colorado State Forest Service, Colorado State University, Fort Collins, Colorado.

This publication is a very helpful resource. It contains good sections on definitions, elements of wildfires, classifications of fuel types, burning characteristics of fuel types, and mitigation procedures for development in these areas. It was prepared to fulfill the mandates of H.B. 1041.

"Model Land Use Regulations - Chapter 5 - Wildfire Hazard Area Regulations".

These regulations were prepared under H.B. 1041 and were adopted on March 26, 1976 by the Colorado Land Use Commission.

Residential Development in the Mountains of Colorado - A Survey of Issues published by the United Banks of Colorado, 1972 by Charles W. Howe.

This report includes good reasoning why steep mountain slopes and valley floors shouldn't develop. It includes a discussion of the major problems and hazards associated with mountain home development of which wildfire hazard is a major component.

"Mountain Comprehensive Plan - Jefferson County" - Wildfire Component, by Guy R. Groves, January, 1976.

This paper discusses the refinement of the Colorado State Forest Service wildfire hazard area mapping to a greater detail for Jefferson

County. Jefferson County has prepared a wildfire algorithm including 14 different vegetation units and 6 varying slope units to produce wildfire value ratings from 0-9. Each wildfire value is described by vegetation unit, slope, fire behavior and land use capabilities.

Manual for Wildfire Hazard Identification and Ecosystem Mapping - Colorado State Forest Service.

This manual is the Colorado State Forest Services' procedures for wildfire hazard area mapping. It is the manual used by the staff of the CSFS. It also includes listing of 18 ecosystems and their descriptions as well as techniques for identification.

An Ecosystem Guide for Mountain Land Planning Level 1, by Dennis L. Lynch, Colorado State Forest Service, Colorado State University.

This report discusses 17 different types of ecosystems common to the mountains in Colorado. They are individually described, usually with an emphasis on vegetative composition. They are each individually evaluated in terms of their dynamics, esthetics, value for wildlife, water table, soil, and hazards of wildfire, avalanche, flood or climatic conditions.

"Mountain Land Planning" by Dennis L. Lynch and Standish R. Broome.

This report has a good discussion of natural hazards including wildfire hazard.

Jefferson County Mountain Area Research Project, Volume 5 Attribute Reports, Report 7 Wildfire Danger; September, 1974.

This report discusses the development of the computer mapping of wildfire hazards in Jefferson County.

REFERENCES NOT PRESENTLY AT DRCOG BUT WHICH SHOULD BE OBTAINED

Rating Forest Fire Hazard in Residential Developments in Colorado Forests by George R. Fahnestock.

This report may be obtained from the Pacific Southwest Forest and Range Experiment Station at Berkely, CA.

WILDFIRE HAZARD AREA MAPS

Adams County Wildfire Areas
  HB 1041 Technical Identification
  Adams County Planning Department
  1" = 4000'

Arapahoe County Fire Hazard Areas
  Tall Grasses
  Arapahoe County Planning Department
  1" = 2000' (set of 2 maps)

Boulder County Wildfire Hazard Area Maps
  Boulder County Planning Department
  1" = 2000'
  Coverage for the following U.S.G.S. quadrangle maps:

- Allens Park
- Boulder
- East Portal
- Eldorado Springs
- Gold Hill
- Isolation Peak
- Lyons
- Nederland
- Raymond
- Tungsten
- Ward

Jefferson County Wildfire Danger
  Jefferson County Planning Department
  1" = 2000'
  (set of 3 maps for the mountainous portion of the county)
  Jefferson County Advanced Planning Computer Map of Wildfire Hazards
  Computer print-out associated with overlay of U.S.G.S. 1:24,000 quadrangle for the mountainous portions of the county.

Wildfire Hazard Area Map
  Colorado State Forest Service
  1" = 2000'; 1973
  Coverage for the following U.S.G.S. quadrangle maps:

- Allens Park
- Boulder
- Castle Rock North
- Castle Rock South
- Cherry Valley School

Conifer
Devils Head
Eldorado Springs
Evergreen
Gold Hill
Greenland
Highlands Ranch
Indian Hills
Kassler
Littleton
Lyons
Morrison
Nederland
Parker
Pine
Piney Creek
Platte Canyon
Ponderosa Park
Ralston Buttes
Raymond
Russellville Gulch
Sedalia
Tungsten
Ward

PERSONAL CONTACTS FOR WILDFIRE HAZARD INFORMATION

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13101 East Mississippi
Aurora, CO
341-7941

Jim Getter
Colorado State Forest Service
Colorado State University
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1-482-8185

Gail Seeburger
Adams County Planning Department
450 South 4th Street
Brighton, CO 80601
(She has wildfire hazard information for the tall grasses
and riparian vegetation in Adams County)

Tom Stamm
Arapahoe County Planning Commission
5606 South Court Place
Littleton, CO 80120
(He has data for grassland wildfire hazards in Arapahoe County)

Pete Fogg
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Courthouse Annex
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Lorraine Seeger
Colorado State Forest Service
Fort Collins, CO
1-482-9512

LANDSLIDES

GEOLOGIC HAZARDS RELATED TO SLOPE FAILURE

Criteria for Specification:

A geologic hazard related to slope failure is defined, for the purposes of this report, as a hazard which results from the failure or slippage of a slope and the resultant downward and outward movement of slope-forming materials such as rock and soil such that property or inhabitants of that area might be damaged, injured or destroyed by the slope failure phenomenon. For the purposes of this report, this type of slope failure phenomenon will basically be referred to as a landslide. The identified areas in the Denver region[1] of past landslide deposits and areas of potential slope failure have been designated as environmental hazard areas.

Basis for Criteria:

A landslide or geologic hazard related to slope failure, is the failure of a slope usually ruptured from a zone of weakness which separates the slide material from the more stable underlying material, and the resultant downward and outward movement of slope forming materials such as soil and rock. The landslide itself can vary in many aspects depending on whether the downslope movement of material is rapid or slow and depending on whether the slope forming material is mainly rock or soil. Various types of slope failure, or landsliding are rockfalls, mudflows or earthflows, soil slump or soil creep.

A rockfall is the downslope movement by means of freefall, rolling, bouncing or sliding of large rock fragments. A mudflow or earthflow is a geologic phenomenon whereby mud and sediment flows relatively rapidly down the mountain watershed usually due to exceedingly high runoff, rainfall or snowmelt. Soil slump is the rapid downslope movement of large portions of the soil mantle due to the pull of gravity usually accelerated by lubrication from excessive rainfall. Soil creep is the slow movement of the soil mantle downslope due to the pull of gravity which is usually accelerated by lubrication from excessive rainfall or runoff.

Another type of slope failure phenonmenon is an avalanche. An avalanche is the rapid downslope movement of snow, ice, rocks, and associated debris such as soil and vegetation, which generate such a force as to directly or indirectly damage or destroy most man-made structures. Avalanches have not been a major problem in the Denver region, and studies on this hazard throughout the region are not available. There are a few areas in Boulder County which are avalanche-prone. These areas are in the Alpine ecosystem but there is only a small amount of privately owned land in these areas where inhabitated structures might be affected.[2] Consequently avalanche-prone areas will not be designated as slope failure hazard areas in this report.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

Many geologic hazards related to slope failure have occurred in the past in the Denver region and have the potential to occur again at some time in the future. However, evidence of past examples of these geologic phenomenon and areas of future potential hazard from slope failures have not yet been completely mapped or studied in detail within this region. Several mapping studies on these geologic hazards have been prepared with most of these studies focusing on the locations of existing landslide deposits.

Studies and maps of known and inferred existing landslide deposits in the Denver region have been mainly prepared by the U.S. Geological Survey. A general study of existing landslide deposits along the Front Range in this region extending westward has been completed by the USGS.[3] In this study, the general category of landslide deposits also includes slide material resulting from not only landsliding but also avalanching, debris sliding, earthflows, mudflows, rockfalls, soil slumping and talus accumulation.

Specific detailed studies on surficial and bedrock geology have been prepared for some areas within the region. This detailed information has been compiled on geologic quadrangle maps (scale 1:24,000) and usually shows existing landslide deposits. These detailed mapping studies are available for only limited portions of the Denver region.

In addition, a few special studies specifically on landslide deposits and areas of potential landsliding, as well as a specific study on rockfalls and areas of potential rockfall have been prepared by the USGS. These studies are for a very limited portion of the region. The USGS has identified areas of potential landsliding in the Morrison Quadrangle and areas of potential rockfall hazard in the Golden quadrangle. Mapping of landslide deposits shows areas where landsliding has occurred in the past. Mapping of areas of potential landslides shows areas which have the potential for slope failure, or landsliding in the future because of unique conditions of degree and aspect of slope, type of bedrock formations, type of surficial material, amount of available moisture, and other factors.

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[2] A Report on the Environmental Geology of Boulder County, Colorado, by Thomas C. Gray, Boulder County Land Use Department, February 1977.

[3] Preliminary Map of Landslide Deposits, Denver 1° x 2° Quadrangle, Greeley 1° x 2° Quadrangle, Colorado, by Roger B. Colton, Jeffrey A. Holligan and Larry W. Anderson, USGS, 1975, Scale 1:250,000

The Boulder County and Jefferson County Planning Departments have also identified slope failure, or landslide hazard areas. The County Geologist for Boulder County[4] has identified and mapped 46 landslide deposits in Boulder County. In addition, the Boulder County Planning Department has prepared geotechnical land use capabilities maps which indicate areas of potential landslide hazard. The more serious potential landslide hazard areas identified by Boulder County are located within the foothills in the general area bounded by the contact between the sedimentary rock formations and the basement complex, and by a slope greater than 20%. The County Geologist for Jefferson County[5] has identified rockfall hazards, landslide hazards and a slope failure complex. The identification of these areas in Jefferson County was based largely on mapping prepared by the U.S. Geological Survey. This mapping is only for specific areas and does not cover the entire county.

No mapping of areas of potential slope failure throughout the entire Denver Region is available at this time. There is a technique that could possibly be used to identify potential landslide areas in the Denver region. However, there are some problems associated with this technique. This technique has been used by the USGS in identifying landslide-prone areas in California--specifically San Mateo County.[6] This study was based on three specific sets of information:

1. The location of existing landslide deposits and occurrences of past landslide activity.
2. Detailed information and mapping of bedrock geology of the study area, and
3. Slope map of the study area.

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[4] Thomas C. Gray is the County Geologist for the Boulder County Planning Department.

[5] Paul Banks is the County Geologist for the Jefferson County Planning Department.

[6] "Landslide Susceptibility in San Mateo County, California" by Earl E. Brabb, Earl H. Pampeyan and Manuel G. Bonilla, U.S. Geological Survey, 1972.

The technique used to determine areas of potential landsliding was to overlay the maps showing the locations of landslide evidence with the slope map and the bedrock geology map. From this comparison, information could be derived as to which geologic formations and which degrees of slope were most likely to fail causing some type of landslide activity. Areas could then be ranked as to their potential of failure based upon past evidences of failure on the same combination of geologic formation and slope.

If this technique were to be applied to the Denver region, the main problem would be in analyzing data on bedrock geology. Some of the USGS quadrangles in this region have been mapped to show bedrock geology--however, this detailed mapping is not available for the entire region. Bedrock geology mapping is available for the entire region, but that mapping is at the gross scale of 1:500,000.

Detailed information on the location of past landslides is available for some portions of this region. However, there would be severe problems of disparities of scale in trying to correlate detailed data on location of evidence of past landslides with a non-detailed map of the geologic units. It would be very difficult to state, with certainty, that most landslides occur on a certain bedrock formation when one is using non-detailed gross scale information on bedrock geology. The slope map needed for this evaluation could be easily prepared, however, the limiting factor of non-detailed bedrock geology would still exist.

All of the above described studies have been used to designate environmental hazard areas in the Denver region. The specific mapping studies used to designate landslides, or geologic hazards related to slope failure, in the Denver region are listed at the end of this report.

As indicated earlier, a landslide is the downward and outward movement of soil, rock, or fill materials. A landslide mass moves along a plane of weakness such as a bedding plane, bentonite surface, clay-filled fracture or water-lubricated bedrock surface.

The stability of a slope, or of inactive landslide deposits, is influenced by many different factors. Such factors include:[7]

- the angular shape of the mineral particles of the rock or soil,
- the tendency of the soil or rock particles to remain together due to attraction and friction,
- the kinds of clay minerals present,

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[7] Map Showing Landslides in the Golden Quadrangle, Jefferson County, Colorado, by Howard E. Simpson, USGS, 1973.

- the amount and direction of attitude (slant) of the layers, that make up the underlying soil or rock material,
- the water content of the slope-forming material,
- the slope of the bedrock material which underlies any loose surface material,
- the external load placed upon the slope, and
- any natural loss or artificial removal of downslope support

In addition, removal of vegetation from slopes will increase runoff, which in turn increases erosion which steepens slopes and might lead to potential landsliding.

A landslide will generally occur when the natural forces that hold rock and soil materials together on a slope are exceeded by other forces such as gravity that move the soil and rock downward. Rock formations and soils are basically held in place by friction and a mutual attraction between the minerals that compose the rock or soil formation. Therefore, when the load on a slope is increased, the friction may be exceeded and slide action may occur. Common ways in which a slope is overloaded are by construction and addition of fill and water. Water acts as a lubricant between soil and rock particles and consequently at times of spring thaws or heavy precipitation and runoff, the water's lubricating effect can reduce the friction between the components of the soil and rock material, and the slope can fail causing a landslide. Earthquake tremors or shaking due to blasting can also reduce the friction between the rock and soil particles and thus cause a landslide or rockfall.

Steep slopes underlain by windblown sand materials are susceptible to failure. Field evidence has indicated that the angle of slope necessary for natural movement of mixed soil and bedrock materials is much greater than is necessary for the natural movement of loose sand material.[8] This situation does change, however, when water is added to these materials. Generally loose or poorly consolidated material is particularly susceptible to landsliding. These materials may fail if they are saturated with water or if they are overloaded by other means without adequate advance measures which would act to prevent landsliding.

Many slopes are held in place by support from debris material that has accumulated at the base of the slope. When this support is removed, either through erosion or some type of excavation for road or building development, a landslide may result.

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[8] Map Showing Potential Landslide Deposits and Areas of Potential Landsliding in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, USGS, Map I-770-E.

A landslide in the form of a rockfall is the rapid movement of a mass of rock by falling, rolling and bouncing outward from a cliff or ledge. The rock usually separates along bedding planes, natural cracks or joints in the rock and then falls freely to the ground. The basic stability of a rock mass is affected by the support provided by underlying rock or earth and the trends, spacing, attitude and extent of joints or cracks in the rock. Once a piece of rock has become dislodged and has fallen, the distance it will roll and the potential area it may cause damage to is affected by many factors. These factors include the form, length and angle of the slope along which the rockfall occurred, the absence of obstructions along this slope, the initial height of the fall, and the size, shape and other characteristics of the rockfall materials.[9] Most rockfalls occur suddenly and without much obvious warning. The probability of rockfalls would, however, increase greatly if an earthquake or blasting in the area would create moderate to severe ground shaking.

Slope failure due to mudflows or soil slump or soil creep are much less dramatic than earth movement due to rapid landslides or rockfalls. Mudlfows and soil slump generally happen when the soil becomes oversaturated with moisture. This excess moisture lessens the friction between the component soil material, lubricates the material so that it can slide more easily, and adds weight to the soil and rock thereby increasing the load and the potential for landsliding. Soil slump usually occurs in homogenous materials such as clay soils, whereas mudflows usually occur in saturated heterogeneous materials such as silt or gravel, and are common occurrences in arid regions during heavy rains.[10] Gradual soil movement (soil creep) may occur on steep slopes especially when a clay or shale layer (whose friction is lessened by lubrication with additional moisture) underlies the surface soil. Such gradual soil creep can damage structures and foundations.

Landslides can be recognized and identified based chiefly on geologic, topographic and cultural evidence. Topographic evidence includes such features as bulging toes, pressure ridges, curved scarps at the top of the landslide, nearly vertical curved cracks in the ground, undrained depressions, rough or hummocky terrain and terracelike benches in the hillside. Geologic evidence includes disturbed earth and rock, moved, displaced or tilted rock strata, seeps and springs, and exposed slide surfaces which may be polished or striated.[11]

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[9] Map Showing Areas of Potential Rockfalls in the Golden Quadrangle, Jefferson County, Colorado, by Howard E. Simpson, USGS, 1973, Map I-761-C.

[10] Performance Controls for Sensitive Lands - A Practical Guide for Local Administrators, ASPO PAS #307, 308 by Charles Thurow, William Toner and Duncan Erley, 1975.

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Active or recent landslides can usually be identified by bare scarps and open cracks in the ground, whereas in an inactive landslide these features are usually subdued or modified by erosion and vegetative cover. Nearly all landslides show a concave depression or trough at the top or upper edge where the material was removed or has slid down the hill. The bottom of a landslide area (toe) is characterized by a convex bulge or linear mound which is composed of the material which has slid down from the top of the landslide area. The thickness of landslide deposits can vary from one foot up to 50 feet.

Easily recognizable cultural evidence of landslides includes curved or displaced fences, tilted or curved tree trunks, broken utility lines and displaced road or railroad alignments. In sloping areas which have been altered and modified by grading and landscaping, the landslide deposits may be difficult to identify. In any area of steep slope composed of clay or shale, where there is evidence of grading, there is generally some potential of a landslide hazard.

At present there is no absolute criteria to indicate which degree of slopes are liable to fail. The potential for failure of a slope, in some form of landslide, depends upon many variables, the most critical of which are the character of the rock formation on the hillside, the amount and availability of moisture and the degree and aspect of the slope. In the Denver region, there are certain rock formations which are more susceptible to landsliding than others. These formations are the Denver Formation, the Morrison Formation, the Benton Formation and the Pierre Shale. However, the slope of the rock on these formations and the available moisture ultimately determine whether or not these formations will fail.

For some portions of the region, (mainly Jefferson County) slope maps have been prepared. The purpose of slope maps is to easily visualize and focus attention on the steeper portions of the region. Slope information is also valuable for planning for development areas, transportation routes, utility lines, sewage disposal, erosion control, foundation suitability, solar exposure, wind exposure and many other items. As indicated earlier there is no absolute criteria to determine slopes which will fail naturally or by the introduction of some type of development. However, past development has indicated the range of slopes

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[11] Preliminary Engineering Geologic Map of The Golden Quadrangle, Jefferson County, Colorado, by Maxwell E. Gardner, Howard E. Simpson, and Stephen S. Hart, U.S. Department of the Interior, Geological Survey, MF-308, 1971.

which can usually safely accomodate certain types of development. A slope of 15% is generally the upper limit for the optimum range of slope for construction of conventional housing.[12] However, a slope in the range of 3-8% is the easiest for housing development. A 15% slope is the absolute cutoff for installation and proper functioning of septic systems based on present technologies according to U. S. Department of Agriculture, Soil Conservation Service evaluation.[13] An 8% slope, however, is generally the highest slope for easy septic system operation. Therefore, development of housing on slopes steeper than 15% would cause very severe limitations for septic system sewage disposal.

Access to property in the mountains is also difficult and costly to construct. A slope of 10% or less is generally needed for construction of all weather roads. With a slope greater than 10% the potential road alignments become very restricted and the amount of cut and fills needed for road construction become excessive. With restricted road alignments there is generally a need for special design of the subdivision. All these problems of restricted alignments, excessive cut and fill,difficult access, and septic system operation problems make mountain development above a 15% slope very difficult and very costly if properly done. When slopes are greater than 30%, the hazard from wildfire increases greatly and when slopes exceed 35-38%, heavy duty rubber-tired construction machines cannot function to construct structures or roads.

It is important to emphasize that the above slope percentage ranges suitable for development are general figures and that individual site specific development situations could alter those figures either upward or downward. A slope of 50% or more on a stable bedrock formation may be less likely to fail in some cases than a slope of 10% or 15% on a weaker or more lubricated bedrock formation. It is also almost impossible to predict when slope failure or landsliding will begin and when it will stop. However, in general, landsliding will occur or reoccur during the wettest times of the year and during the wettest years.[14]

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[12] Slope Map of the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, USGS, 1972.

[13] Conversation with Rachael Barker, USGS, Reston, Virginia, 3-15-77.

[14] Map Showing Landslides in the Golden Quadrangle, Jefferson County, Colorado, by Howard E. Simpson, USGS, Map I-761-B, 1973.

Landslide deposits represent a record of past slope failure but they are not necessarily proof of present or future slope instability. The presence of a landslide deposit, whether active or inactive, acts as a warning of the potential instability of the slopes in that general area. Naturally occurring landslides that have been inactive for very long periods of time may, however, be activated again so as to cause new destruction. They may be activated by such activity as excavating the lower mass of a landslide for the building of a road, by construction associated with a development project, by changes in natural drainage patterns, or even by watering a lawn or adding water to the subsoil from septic systems. In addition, landsliding can occur upslope from existing mapped landslide deposits.

Areas of past and potential slope failure have been designated as environmentally significant areas because they are geologic hazard areas and present a threat to existing or future development on or near them. In some areas of the Denver region, landslide movements have damaged and destroyed highways and buildings and have buried cables, pipelines and other utilities. The movement of a landslide mass oftentimes causes settlement of buildings, roads or other structures placed upon the landslide material. Generally this settlement is uneven because the amount and direction of movement, as well as the rate at which the movement occurs, varies significantly from one part of the landslide to another. Damage from this uneven settlement results in cracked ceilings, walls, windows, floors and foundations.

Slopes of hillsides are special geologic features where the slope, and soil and rock material on the slope, are in a balance with vegetation, precipitation amounts, forces of gravity and the character of the underlying geology of the hillside. When the balance, or equilibrium, of the hillside slope is disturbed or altered either through natural environmental factors or through human activity, the slope is liable to fail resulting in some form of landslide which may pose a threat to life and property in the path of the landslide.

Many other problems besides the threat to life and property due to landslides, are associated with disturbance or development of hillside slopes. When a slope fails and the hillside balance of soil, vegetation, etc. is upset, erosion of the exposed soil and rock material will be accelerated. This increased erosion causes a degradation of downslope or downstream water quality. Hillside runoff is also increased when vegetation and stable soil cannot readily accept rainfall and runoff. This increased runoff may alter natural drainage patterns and may also decrease the amount of groundwater storage and recharge since more rainwater will take the form of runoff rather than percolating through the vegetation and surface soil down to the ground water table.

In addition to the problems of potential damage to property, increased runoff and erosion, slope failure is damaging to the visual aesthetics of slopes and mountainsides. Many of the communities in the Denver region have scenic mountains nearby that provide a beautiful background setting for development of homes and other buildings. The degration and scarring of these mountainsides by landslides induced by improper development could drastically change a spectacularly scenic mountain setting into a blatantly ugly scarred reminder of a lack of respect for the balance of nature. In the Denver region, the flanks of the Table Mountains and Green Mountain in Jefferson County exhibit prominent scars from landsliding, some of which have been overgrown with vegetation.

As is often the case with development on other environmental hazard areas, poorly designed and constructed development on slopes can frequently result in excessive costs to individuals and the general public. These costs are either for repairs to the damage which results from the improper development or for protective measures to prevent further damage. In addition, public expenditures for flood control and storm water management which are required as a result of increased runoff and sedimentation from denuded hillsides are increased by improper development on slopes.

This report discussed mainly identified areas of past and potential slope failure or landslide hazard. It is important to bear in mind that other steep slopes in this region which have not yet failed or which have not been specifically studied for the potential of failure, are also potential slope failure hazard areas when their existing natural balance is altered by man's or nature's activities. Caution is also especially advised in considering developments on slopes that are underlain by the same surficial deposits or bedrock units that are known or inferred, to have failed and caused sliding in other areas.

MAPPING STUDIES USED IN DESIGNATING GEOLOGIC HAZARDS RELATED TO SLOPE FAILURE IN THE DENVER REGION

Map Showing Landslides in the Golden Quadrangle, Jefferson County, Colorado
by Howard E. Simpson, U.S. Geological Survey, 1973
Map I-761-B

Scale 1:24,000

Map Showing Areas of Potential Rockfalls in the Golden Quadrangle, Jefferson County, Colorado
by Howard E. Simpson, U.S. Geological Survey, 1973
Map I-761-C

Scale 1:24,000

Jefferson County Geologic Hazard Overlay Zoning Map of the Golden Quadrangle
prepared by Jefferson County Planning Department, 1976
Map Shows:
1. Rockfall Hazard
2. Landslide Hazard
3. Slope Failure Complex

Scale 1:24,000

Map Showing Landslides and Areas Susceptible to Landsliding in the Morrison Quadrangle, Jefferson County, Colorado
by Glenn R. Scott, U.S. Geological Survey, 1972
Map I-790-B

Scale 1:24,000

Reconnaissance Map Showing Relative Amounts of Soil and Bedrock in the Mountainous Part of the Morrison-Evergreen Quadrangles and Adjoining Areas to the West in Jefferson County, Colorado
by Paul W. Schmidt, U.S. Geological Survey, 1976
Map MF-740

Scale 1:24,000

Jefferson County Geologic Hazard Overlay Zoning Map of the Morrison Quadrangle
prepared by Jefferson County Planning Department, 1976
Map Shows: 1. Rockfall Hazard
2. Landslide Hazard
3. Slope Failure Complex

Scale 1:24,000

Geologic Map of the Lafayette Quadrangle, Adams, Boulder, and Jefferson Counties, Colorado
by Michael N. Machette, U.S. Geological Survey, 1975
Map MF-656

Scale 1:24,000

Reconnaissance Map Showing Relative Amounts of Soil and Bedrock in the Mountainous Part of the Indian Hills Quadrangle in Jefferson County, Colorado
by Paul W. Schmidt, U.S. Geological Survey, 1976
Map MF-741

Scale 1:24,000

Geologic Map and Engineering Data for the Highlands Ranch Quadrangle, Arapahoe and Douglas Counties, Colorado
by John O. Maberry and Robert M. Lindvall, U.S. Geological Survey, 1974
Map MF-631

Scale 1:24,000

Reconnaissance Geologic Map of the Pine Quadrangle, Jefferson County, Colorado
by Bruce Bryant, U.S. Geological Survey, 1974
Map MF-598

Scale 1:24,000

Preliminary Engineering Geologic Map and Sections of the Eldorado Springs Quadrangle, Boulder and Jefferson Counties, Colorado
by Maxwell E. Gardner, U.S. Geological Survey, 1969

Scale 1:24,000

Preliminary Engineering Geologic Map of the Boulder Quadrangle, Boulder County, Colorado
by Maxwell E. Gardner, U.S. Geological Survey, 1968

Scale 1:24,000

Geologic Map of the Arvada Quadrangle, Adams, Denver, and Jefferson Counties, Colorado
by Robert M. Lindvall, U.S. Geological Survey, 1972
Map MF-348

Scale 1:24,000

Map Showing Landslide Deposits and Areas of Potential Landsliding in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado
by John O. Maberry, U.S. Geological Survey, 1972
Map I-770-E

Scale 1:24,000

Jefferson County Geologic Hazard Overlay Zoning Map of the Louisville Quadrangle
prepared by Jefferson County Planning Department, 1976
Map Shows:
1. Rockfall Hazard
2. Landslide Hazard
3. Slope Failure Complex

Scale 1:24,000

Jefferson County Geologic Hazard Overlay Zoning Map of the Evergreen Quadrangle
prepared by Jefferson County Planning Department, 1976
Map Shows:
1. Rockfall Hazard
2. Landslide Hazard
3. Slope Failure Complex

Scale 1:24,000

Preliminary Map of Landslide Deposits, Denver 1°x 2° Quadrangle, Colorado
by Roger B. Colton, Jeffrey A. Holligan, and Larry W. Anderson,
U.S. Geological Survey, 1975
Map MF-705

Scale 1:250,000

Preliminary Map of Landslide Deposits, Greeley 1° x 2° Quadrangle, Colorado
by Roger B. Colton, Jeffrey A. Holligan, and Larry W. Anderson,
U.S. Geological Survey, 1975
Map MF-704

Scale 1:250,000

Maps of Landslide Deposits in Boulder County, Colorado,
by Thomas C. Gray, Boulder County Geologist
Boulder County Land Use Department

Scale 1:24,000

Maps for the following U.S.G.S. Quadrangles:

- Boulder
- Carter Lake Reservoir
- Eldorado Springs
- Hygiene
- Louisville
- Lyons

Geotechnical Land Use Capability
Boulder County Land Use Department, 1977
Scale 1" = 5000' (1:60,000)

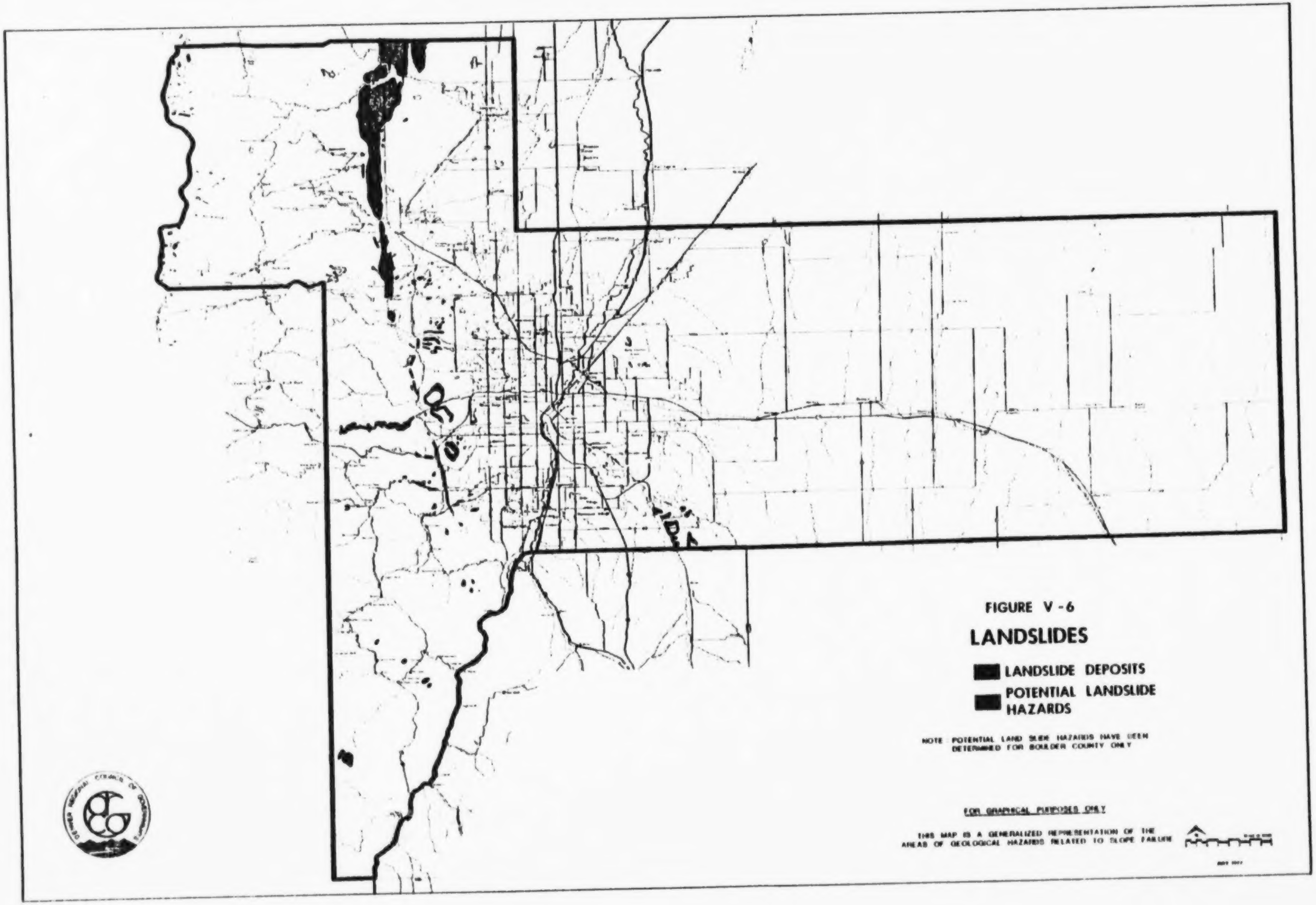

FIGURE V-6

LANDSLIDES

▇ LANDSLIDE DEPOSITS

▇ POTENTIAL LANDSLIDE HAZARDS

NOTE: POTENTIAL LAND SLIDE HAZARDS HAVE BEEN DETERMINED FOR BOULDER COUNTY ONLY

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF THE AREAS OF GEOLOGICAL HAZARDS RELATED TO SLOPE FAILURE

BIBLIOGRAPHY FOR GEOLOGIC HAZARDS RELATED TO SLOPE FAILURE

Sources Available at DRCOG

REFERENCES FOR GEOLOGIC HAZARDS RELATED TO SLOPE FAILURE

Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators, by Charles Thurow, William Toner and Duncan Erley, American Society of Planning Officials, Planning Advisory Service Report #307, 308, June 1975.

This report discusses problems associated with development on hillside slopes including the potential of landslides, rockfalls, and soil movement.

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas, by W. P. Rogers, L. R. Ladwig, A. L. Hornbaker, S. D. Schwochow, S. S. Hart, D. C. Shelton, D. L. Scroggs and J. M. Soule, Colorado Geological Survey, Special Publication No. 6, published in 1974.

This report discusses unstable or potentially unstable slopes, avalanches, landslides, rockfalls, mudflows and debris fans. For each of these geologic hazards some criteria for recognition, and mitigation procedures necessary for safe and proper land use are discussed.

Earth and Man, by Frank Byrne.

This geology textbook includes a section on soil and rock movement. Included are discussions of mudflows, soil creep, soil slump, rockfalls, and landslides.

"Mountain Land Planning," by Dennis L. Lynch and Standish R. Broome, September 1973.

This booklet discusses factors which should be considered in mountain land planning. It also discusses hazards to planning in the mountains and some of the problems that can occur because of improper mountain development.

Residential Development in the Mountains of Colorado - A Survey of Issues, Charles W. Howe, 1972.

This report was prepared for the United Banks of Colorado, Inc. It discusses problems associated with development on steep mountain slopes.

"Geologic Aspects, Soils and Related Foundation Problems, Denver Metropolitan Area, CO," by Judith L. Hamilton and Willard G. Owens, prepared for the Colorado Geological Survey, 1972, Environmental Geology Report #1.

This report discusses many of the geologic hazards in the Denver region including landslides.

"Map Showing Landslide Deposits and Areas of Potential Landsliding in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado," by John O. Maberry, U.S. Geological Survey, 1972.

This map includes a written description of how landslides occur, and which of man's activities can cause landsliding.

"Map Showing Landslides in the Golden Quadrangle, Jefferson County, Colorado, by Howard E. Simpson, U.S. Geological Survey, 1973.

This map includes a written explanation of the character of landslides, ways to recognize landslides, and damage that can result from landslides.

"Map Showing Areas of Potential Rockfalls in the Golden Quadrangle, Jefferson County, Colorado," by Howard E. Simpson, U.S. Geological Survey, 1973.

This map includes a written explanation of how and when rockfalls occur and how they can be prevented.

"Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado," by Maxwell E. Gardner, Howard E. Simpson, and Stephen S. Hart, U.S. Geological Survey, 1971.

This map includes an explanation of the geologic formations and depositions in the Golden quadrangle. Included is a discussion of slope stability and the factors which influence it.

"Geologic Map of the Arvada Quadrangle, Adams, Denver and Jefferson Counties, Colorado," by Robert M. Lindvall, U.S. Geological Survey, 1972.

This map includes a written description of the composition of the mapped landslide deposits.

"Preliminary Map of Landslide Deposits, Denver 1° x 2° Quadrangle, Colorado," by Roger B. Colton, Jeffrey A. Holligan, and Larry W. Anderson, U.S. Geological Survey, 1975.

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Slope Map of the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, U.S. Geological Survey, 1972.

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"Landslide Susceptibility in San Mateo County, California" by Earl E. Brabb, Earl H. Pampeyan and Manuel G. Bonilla, U.S. Geological Survey, 1972.

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(2) Landslide Hazard
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Map shows: (1) Rockfall Hazard
(2) Landslide Hazard
(3) Slope Failure Complex
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Jefferson County Geologic Hazard Overlay Zoning Map of the Evergreen Quadrangle, prepared by Jefferson County Planning Department, 1976. Map shows: (1) Rockfall Hazard
(2) Landslide Hazard
(3) Slope Failure Complex
Scale 1:24,000.

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Map MF-360
Scale 1:62,500

Jefferson County Planning Department Slope Map.
Scale 1:24,000
Set of 7 maps

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SUBSIDENCE HAZARD AREAS

Criteria for Specification

Those areas of the Boulder-Weld coalfield which have been designated as having a severe, moderate, or low subsidence hazard have been designated as environmental hazard areas in the Denver Region.

A severe subsidence hazard area is an area in which rapid and violent effects of subsidence such as building foundation, gas main or road failure may endanger persons in the immediate vicinity. These areas have been undermined and are characterized by: (1) the presence of support pillars (which are assumed to be undergoing decomposition) plus physical evidence of void space, or (2) by the absence of evidence of past surface subsidence. The collapse of support pillars which have decomposed could alter the stress and strain patterns in the overlying rock resulting in almost instant subsidence and resultant damage or destruction of structures at the surface.

A moderate subsidence hazard area includes those areas in which the effect of subsidence might cause enough disruption to the overlying land surface to damage structures to such an extent that they are unsafe or no longer usable. The rate of subsidence in a moderate hazard area would, however, be slow enough to allow for recognition of the problem and for a safe abandonment of the structure. These areas show evidence of past subsidence over undermined areas where pillars are reported to be present. This condition produces the potential for additional future small scale subsidence and differential settlement.

The low subsidence hazard areas are those areas where any anticipated surface displacement or settlement are small enough such that the damaged structure would warrant repair. With adequate engineering design, future structures could be constructed in these areas such that they could withstand the anticipated stresses on the buildings' foundations. Below these low hazard areas, all or essentially all foundation pillars have already been removed and so relatively uniform and total subsidence has already occurred. The potential problems in these areas are largely post-subsidence compaction, related surface settling and small scale effects from sub-surface shifting which results from any small residual or secondary voids.

Coal mining has also occurred in Jefferson County in the Foothills Mining district. An in-depth study of these mined out areas is underway at this time but is not complete yet and consequently the severity of the potential subsidence hazard has not been determined. However, data is available which shows the general boundaries of these mined out areas in the Foothills coal district in Jefferson County and consequently these areas have been designated as potential subsidence hazard areas.

Basis for Criteria

Ground subsidence, as legally defined by the State of Colorado, House Bill 1041[1] means "a process characterized by the downward displacement of surface material caused by natural phenomena such as removal of underground fluids, natural consolidation, or dissolution of underground minerals, or by man-made phenomena such as underground mining." The amount and severity of surface subsidence is generally determined by the amount of material that is compressed or that has been removed, the depth between the ground surface and the location of the removed material or compaction, and the basic geologic conditions of the particular site. The amount of faulting in the rock strata is also significant in determining the location and severity of subsidence.

In addition to ground collapse due to underground mining, subsidence can occur because of a withdrawal of pore fluids such as ground water, by hydrocompaction from excessive wetting of certain low density weak soils, and by dissolution of soluble rock or soil materials. Subsidence due to withdrawal of groundwater has not been a serious problem in Colorado in the past. Some areas of the State do have very thick and extensive alluvial aquifers and these areas might be subject to subsidence problems if large amounts of groundwater are withdrawn in the future.

Subsidence due to hydrocompaction will occur generally on low-density wind-deposited soils and predominantly fine-grained colluvial soils. In these cases the collapse occurs from the excessive wetting of previously dry collapsible soils. Wetting of these soils will weaken the soil structure which can produce ground surface collapse when pressure is applied in the vicinity of the excessive wetting. At the present time, the hazard of settling soil or subsidence due to hydrocompaction cannot be adequately delineated due to a lack of regionwide detailed mapping of the location and thickness of separate units of loess, eolian sand, and colluvium. In the Denver region, some subsidence due to hydrocompaction occurred when loess and eolian soils south of Lafayette were trenched for installation of utilities, but subsidence due to hydrocompaction is generally not a severe problem in the Denver region.[2]

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[1] Ground subsidence is defined in H.B. 1041, Section 106-7-103 (10), which was passed in 1974 by the Colorado State Legislature.

Subsidence resulting from the dissolution of soluble rock or soil will generally occur in areas underlain by such soluble materials as gypsum, halite and to a lesser extent, limestone. Natural solution will occur from downward percolation of ground water. Dissolution can also be caused by hydrologic processes induced by man's activities, including stream channel changes, ponding of surface waters, and irrigation ditches. Large areas in western Colorado are underlain by soluble rock which may be susceptible to such subsidence[3], but such subsidence due to dissolution has not yet been a big problem for the Denver region.

The magnitude of the subsidence hazard caused by the above factors varies. Subsidence resulting from excessive withdrawal of groundwater, hydrocompaction of low density soil and bedrock, or dissolution of soluble rock materials are all of a much smaller magnitude in the Denver region than the subsidence which occurs when materials collapse over an undermined area. Consequently, in the Denver region study efforts on subsidence hazards have focused on the more severe subsidence hazard in the undermined areas of the Boulder-Weld coalfield. At this time an additional subsidence hazard study is in progress for the mined out areas in the Foothills coal district, which generally extends along the outcrop of the Laramie formation from approximately Leyden south to Chatfield. No specific studies have been made on the subsidence hazard in this region from the other three factors mentioned above. It should, however, be recognized that subsidence can be a problem over aquifers experiencing excessive amounts of groundwater withdrawal, over the loess, colluvium and some younger alluvium deposits when they experience excessive wetting along with applied pressure, and over some of the soluble rock formations such as gypsum and halite.

The criteria which were stated earlier for use in designating subsidence hazard areas in the Denver region have been applied only to undermined areas in the Boulder-Weld coalfield. These criteria were chosen for specification of subsidence hazard areas based upon studies and mapping prepared for the Colorado Geological Survey (CGS) in 1975.[4] It is important to note the state of the art of subsidence hazard evaluation and subsidence control is not as advanced as is the evaluation and control of many other geological hazards. At this time much of the past information on the control and evaluation of subsidence hazards is based upon European experience. However, direct application of such experience to the control of subsidence hazard in the United States is not always feasible because of differences in mining techniques and differences in the strength and types of overlying rock. As a result of these problems, professional opinion differs substantially as to what actually constitutes a subsidence hazard. The CGS study on subsidence included all mined out areas in the Boulder-Weld coalfield. Since the publication of that study, there has been a more site-specific study for the area immediately southeast of Louisville.[5] The areas designated as a subsidence hazard in that study are much less extensive than the areas designated as a severe subsidence hazard by the CGS. As additional information becomes available that might solidify professional opinions on what constitutes a subsidence hazard and which might alter areas which are presently identified as subsidence hazard areas, the delineation of subsidence hazard areas will be modified accordingly.

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[2] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

[3] Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas by W.P. Rogers, L. R. Ladwig, A. L. Hornbaker, S. D. Schwochow, S. S. Hart, D. C. Shelton, D. L. Scroggs and J. M. Soule, Colorado Geological Survey Special Publication #6, 1974.

The CGS subsidence study was prepared to provide basic data regarding past and possible future subsidence in the Boulder-Weld coalfield. The study mapped the extent of past mining as accurately as possible and defined the physical factors which effect subsidence. Such factors include the depth of cover above the mine cavity, the thickness of the lens of coal which has been extracted, the amount of coal pillar removal and the time period of the active mining.

The Boulder-Weld coalfield is located about 20 miles from Denver. It occurs in the southeastern portion of Boulder County, the northwestern tip of Adams County and the southwestern portion of Weld County. Much of the land between the towns of Marshall in Boulder County and Firestone in Weld County has been undermined for coal. The abandoned coal mines lie at depths of 30 to 580 feet below the ground surface with the majority of the mines within the 100 to 300 foot depth range.

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[4] Coal Mine Subsidence and Land Use in the Boulder-Weld Coalfield - Boulder and Weld Counties, Colorado, prepared for the Colorado Geological Survey by Amuedo and Ivey Consulting Geologists, A.R. Myers, J.B. Hansen, R.A. Lindvall, J.B. Ivey, and J.L. Hynes, March, 1975, Environmental Geology Report #9.

[5] Engineering Geology and Mineral Resources - Colorado Technological Center, Louisville, Colorado by Charles S. Robinson and Associates, prepared for Mizel Development Corporation, June 1976.

The area of the Boulder-Weld coalfield is underlain by two basic bedrock units, the Fox Hills Sandstone and the Laramie Formation. The coal beds which have been mined in the Boulder-Weld coalfield all occur within the Laramie Formation. This formation is composed of interbedded shales, sandy shales, claystones, coalbeds and thin beds of sandstone.[6] Generally, these rock strata are subject to a relatively rapid collapse if they are undermined and then left unsupported. The portion of the bedrock strata that forms the floor of a mine also affects subsidence. A hard floor of sandstone or other resistant rock might support a standing coal pillar and the overlying strata that the pillar supports, whereas, a soft shale or clay might allow the pillar to sink into the floor causing some surface settlement and possibly a redistribution of supported weight on the pillars that might also cause subsidence. Because of these differential settlements based upon the rock strata of the mine floor one should assume that mines with a hard floor and standing support pillars have a greater percentage of void space in them than do mines with soft floors.

Subsidence has occurred in the Boulder-Weld coalfield in the past and there is the potential of future subsidence. Most of the mining in the Boulder-Weld coalfield has been by the underground room and pillar method. Historically, it was a common practice to mine or remove as many of the support pillars as possible immediately before a company would end its mining operation at a set location. This pillar removal resulted in subsidence in most areas. The pillars which remain will continue to support the mine roofs and overlying strata until those pillars decompose to the point where they can no longer support the overlying material.

The subsidence hazard mapping prepared for the CGS designated those areas where development on the land surface might be affected by subsidence due to underground mining. In order to develop the subsidence hazard maps, a battery of individual mining factor maps were prepared. This mapping includes maps showing: (1) the present extent of mined-out areas, (2) the depth of the cover material from the ground surface to the roof of the mined areas, (3) the location of remaining pillars in mined areas, (4) the probable thickness of the extracted coal, and (5) an inventory of existing areas of subsidence. The extent of existing areas of subsidence was fairly well defined by field observations. Strong evidence of surface subsidence consists of well defined depressions and pits. Less defined evidence of surface subsidence consists of broad swales and shallow poorly drained depressions.[7]

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[6] Colorado Geological Survey Environmental Geology Report #9, March 1975.

[7] Colorado Geological Survey Environmental Geology Report #9, March 1975.

In areas where there was a depth of cover from 200 to 300 feet, the instances of surface subsidence evidence have occurred three times as often over areas where pillars were absent as over areas where pillars still existed. In those cases where the depth of cover was greater than 300 feet instances of surface subsidence evidence have occurred twice as often over areas where pillars are absent as over areas where the pillars are present.[8] These relationships show that as the depth of cover increases to 300 feet, evidence of subsidence over areas where pillars are absent is much more frequent relative to those areas where pillars are still present. However, when the depth of cover is greater than 300 feet this trend is reversed. It is obvious that such comparisons and inferred relationships can only be made where evidence of subsidence exists. In areas where there is no surface evidence of subsidence one must be very careful about drawing any conclusions from such inferred relationships.

No consistent criteria can be established to predict subsidence in previously mined areas of the Boulder-Weld coalfield because of a lack of knowledge as to the exact limits of all mining, the precise locations of remaining pillars, the state of decomposition of the remaining pillars or the exact location of all areas that have subsided. Consequently, the best way to address the subsidence hazard problem is by designating areas according to the probable severity of subsidence. In order to classify the probable severity of the hazard, the CGS set forth certain basic assumptions. These assumptions are:[9]

(1) Large undermined areas which have had the pillars removed will subside within months after the pillars are removed.

(2) Caving proceeds upward from the roof of the mine to the ground surface and by the time the collapse effects have reached the ground surface it can be expected that no large voids remain beneath that particular area.

(3) In areas where subsidence is visible at the ground surface, it is assumed that the subsidence at that particular site is essentially complete.

(4) All existing pillars will continue to undergo decomposition and eventually fail. Consequently, it is assumed that subsidence will probably occur over all voids in mined-out areas in the Boulder-Weld coalfield.

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[8] Colorado Geological Survey Environmental Geology Report #9, March 1975.

[9] Colorado Geological Survey Environmental Geology Report #9, March 1975.

Based upon these assumptions, a subsidence hazard map showing areas of low, moderate, and severe potential subsidence hazard was prepared. These three categories are based upon knowledge of the occurance of factors which effect subsidence in the area and associated estimates on the relative level of danger to which persons and structures may be subjected should subsidence occur in the future.

Two other subsidence hazard studies have been prepared for certain areas of the Denver region. One of these studies evaluates the subsidence potential of the land over the Nonpariel,Old Centennial, New Centennial, and Regal Mines in Sections 15 and 16 TIS, R69W. These old mines are located southeast of the developed parts of the City of Louisville. This study was based partly upon an evaluation of six drill holes and 11 soil test borings on the 720 acre study area.

Based upon the consultant's analysis in this study, the following four different categories of subsidence potential were assigned to the study areas:[10]

(1) No possibility of subsidence.

(2) Undermined areas where failure has already occurred. Subsidence potential less than one percent chance within 100 years.

(3) Undermined areas where there is no evidence that subsidence has not occurred, but based on the best data available- subsidence should have occurred. Subsidence potential one to ten percent chance that some portion of the area will subside within 100 years.

(4) Areas around openings from the mines to the surface including working shafts, inclines or air shafts.

The consultant determined that categories 3 and 4 represented a subsidence hazard and consequently the City of Louisville has designated the areas in categories three and four (approximately eight acres) as geologic hazards under the State H.B. 1041 program. However, the Louisville Plan Update (current through 01/27/77) shows geologic hazards based on the previously mentioned Colorado Geological Survey study. That study shows a much more extensive area as a subsidence hazard area. The Louisville Plan Update has classified these more extensive areas as "identified areas and activities of

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[10] Engineering Geology and Mineral Resources - Colorado Technological Center, Louisville, Colorado by Charles S. Robinson and Associates, prepared for Mizel Development Corporation, June 1976.

State interest" and they are administered under the City of Louisville Ordinance No. 507 adopted December 21, 1976. The specific hazard areas, which were designated under H.B. 1041 as areas of State interest by the City of Louisville, are all contained within the larger areas identified as a severe subsidence hazard by the Colorado Geological Survey.

The other subsidence hazard study in this region was compiled by the Boulder County Planning Department. The subsidence hazards are discussed in a publication entitled "A Report on the Environmental Geology of Boulder County, Colorado" and on associated maps entitled "Geotechnical Land Use Capability." The areas shown as having subsidence potential are the same areas designated in the CGS subsidence study.

As indicated earlier, past special studies on subsidence hazards in this region have all been on the Boulder-Weld coalfield. Mining has occurred in the Foothills mining district in Jefferson County, but a completed subsidence hazard map has not yet been prepared. Some data, which shows the general boundary of mined-out areas in Jefferson County, does exist and this information has been used to designate areas that may have the potential to subside but for which no ranking of the hazard potential (i.e. severe, moderate, low) has been completed.

An undermined area is a potential environmental hazard because of the threat to life and property from the occurrence of subsidence or ground collapse. In addition, excessive economic losses can result from subsidence in areas where development has occurred over undermined areas. These losses are in the form of repairs and maintenance costs for highways, buildings, utilities and other structures. The damage from subsidence includes buckled or caved in streets, highways and sidewalks, heavily damaged homes or other buildings and ruptured or broken utility lines. Gas lines which have been ruptured or broken due to subsidence can cause a serious hazard due to the possibility of a gas explosion. People living in homes or working in buildings in areas where subsidence occurs have been forced to abandon their homes in cases where the damage is very severe, or to make structural improvements to hold up the parts of the structure that are sinking due to the shifting and collapse of the underlying material. In addition to the immediate economic loss from damage to the structure, owners of buildings in areas of subsidence can expect substantial decreases in property values in and around areas where there is evidence of subsidence.

Even though damage to property and structures is the main or most visual effect of subsidence, there are other indirect widespread effects. The threat of future subsidence tends to discourage property investment and maintenance, reduces the attractiveness of the threatened area and reduces land values. Another problem is the long term of the subsidence threat. It is very difficult to predict just when subsidence will commence and whether or not the subsidence is complete or only partial and subject to additional settlement sometime in the future. The social and psychological effects that linger with the subject property owners and adjacent property owners after the subsidence incidence are often as damaging as the actual and direct loss to the property.

Evidences of subsidence do exist in the Denver region. One of the more recent was August 29, 1974 in a mobile home park in Lafayette. The collapse hole was near a mine shaft and measured 24 feet by 18 feet by 16 feet[11]with a calculated volume of about 190 cubic yards.

There are several possible alternatives for dealing with potential subsidence problems. These include: (1) land use planning to avoid or minimize development over undermined areas, (2) construction of buildings which are designed to be relatively resistant to subsidence damage, (3) purchase insurance protection (if available), (4) accept the risks of possible damage and learn to live with expectations of such damage, or (5) mitigate the threat of subsidence by such subsidence control programs as backfilling the mined-out voids or providing additional support to supplement existing subsurface support and consequently prevent or minimize subsidence movements.

Subsidence control techniques include filling methods to eliminate the void such as hydraulic flushing or backfilling, pneumatic filling (transport and placement of fill material by air pressure), fly ash injection, grouting (hydraulic flushing with cementitous additives in the backfill) and blasting.[12] All of these methods of surface stabilization are expensive such that the stabilization expense is equal to several percent of the value of the land surface which is protected, and in some cases these costs may exceed the value of the property. For a subsidence control project to be as effective as possible the surface stabilization should be applied on a large scale rather than on only a few specific sites in the subsidence hazard area.

At any location where a potential subsidence hazard exists, it is very important that a thorough on-site and sub-surface investigation be made to determine the nature and extent of subsidence in that particular location. With adequate knowledge of the size and character of the void, the extent of pillar support, the rock strata of the mine floor and the depth of overburden, a knowledgeable decision can be made regarding the future development potential of that site and what type of subsidence control measures (if any) would make that site safe for development.

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[11] A Report on the Environmental Geology of Boulder County, Colorado by Tom Gray, Boulder County Geologist, February 1977.

[12] State of the Art of Subsidence Control by General Analytics for Appalachian Regional Commission and the Pennsylvania Department of Environmental Resources.

MAPPING STUDIES USED IN DESIGNATING SUBSIDENCE HAZARD AREAS IN THE DENVER REGION

Ground Subsidence and Land Use Considerations Over Coal Mines in the Boulder-Weld Coalfield, Colorado, Subsidence Hazard Map (Plate 6), by Amuedo and Ivey, Geological Consultants for the Colorado Geological Survey, 1975, Environmental Geology Report #9, Scale 1:24,000.

Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado, by Maxwell E. Gardner, Howard E. Simpson, and Stephen S. Hart, U.S. Geological Survey, 1971, Front Range Urban Corridor, Colorado, Environmental Geologic and Hydrologic Studies, MF-308, Scale 1:24,000.

Coal Mines of Colorado - Jefferson County, prepared by the Colorado School of Mines Foundation, Inc., 1964, Scale 1" = 1 Mile.

Engineering Geology and Mineral Resources, Colorado Technological Center, Louisville, Colorado, by Charles S. Robinson and Associates, June 1976. Subsidence Potential Map of Colorado Technological Center, Louisville, Colorado (Figure 3), Scale 1" = 200 Feet.

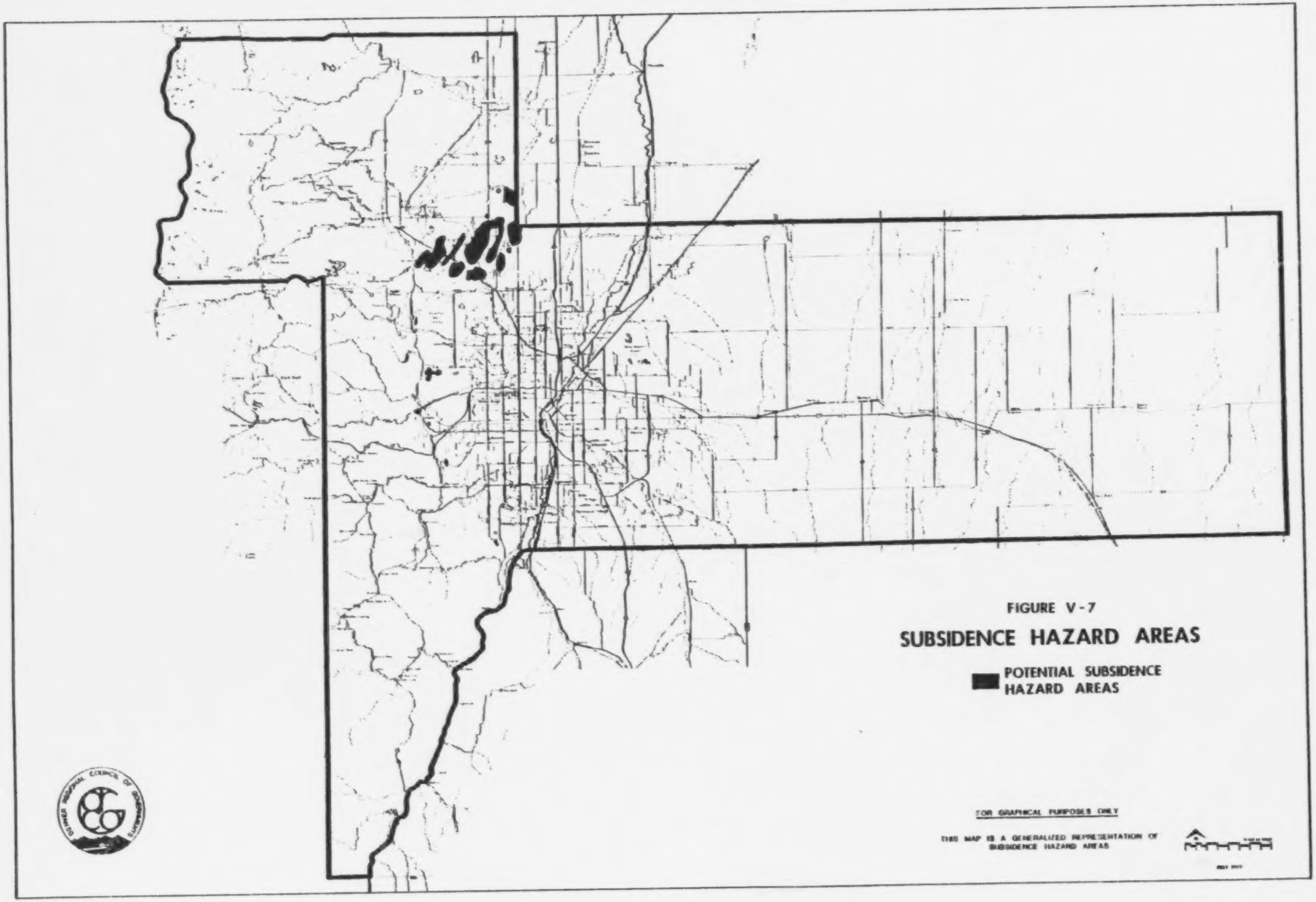

FIGURE V-7

SUBSIDENCE HAZARD AREAS

■ POTENTIAL SUBSIDENCE HAZARD AREAS

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF SUBSIDENCE HAZARD AREAS

DENVER REGIONAL COUNCIL OF GOVERNMENTS

BIBLIOGRAPHY FOR SUBSIDENCE

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This report analyzes the extent of mining and evidence of subsidence in the Boulder-Weld Coalfield. Also included is a subsidence hazard map delineating the severity of the hazard associated with potential subsidence areas. Included with the study is a packet of six maps which show:

(1) Extent of Mining
(2) Depth of Cover
(3) Mine Pillars
(4) Probable Thickness of Extracted Coal
(5) Subsidence Inventory
(6) Subsidence Hazard

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas, by W. P. Rogers, L. R. Ladwig, A. L. Hornbaker, S. D. Schwochow, S. S. Hart, D. C. Shelton, D. L. Scroggs and J. M. Soule, Colorado Geological Survey Special Publication #6, 1974.

This report discusses geologic hazards including ground subsidence. It describes the natural and man-made processes which create a hazard for potential subsidence, and describes ways to identify and mitigate the problem.

Surface Subsidence Control in Mining Regions - Final Environmental Impact Statement, U.S. Department of the Interior, Bureau of Mines, November 1976.

This EIS evaluates the impacts associated with backfilling areas where underground minerals and fuels are mined and removed.

City of Louisville Ordinance No. 507.

"Comprehensive Development Plan Update, Louisville, Colorado," by Oblinger-Smith Corporation and Drumm and Associates.

This report includes a description of areas identified as geologic hazards due to the potential of subsidence over mined-out areas.

Engineering Geology and Mineral Resources Colorado Technological Center, Louisville, Colorado, by Charles S. Robinson and Associates, prepared for Mizel Development Corporation, June 1976.

This study analyzes the subsidence hazard over the Nonpariel, Old Centennial, New Centennial, and Regal Mines located southeast of the developed portions of the City of Louisville.

Demonstration of a Technique for Limiting the Subsidence of Land Over Abandoned Mines, Final Report, Rock Springs, Wyoming, by Candeub, Flessig and Associates, November 1973.

This report discusses the damages from subsidence in Rock Springs, Wyoming. It also discusses backfilling techniques used to prevent and alleviate subsidence over mined-out areas.

A Report on the Environmental Geology of Boulder County, Colorado, by Thomas C. Gray, County Geologist, Boulder County Land Use Department, February 1977.

This report discusses the soil and geologic conditions in Boulder County and geotechnical planning considerations for dealing with geologic hazard areas.

Geologic Map of the Lafayette Quadrangle, Adams, Boulder, and Jefferson Counties, Colorado, by Michael N. Machette, U.S. Geological Survey, 1975.

This map includes a written description of a ground collapse near an old coal mine shaft in Lafayette.

State of the Art of Subsidence Control, prepared by General Analytics for Appalachian Regional Commission and Pennsylvania Department of Environmental Resources, December 1974.

This report includes in-depth discussion of techniques for mitigating subsidence hazards. Subsidence control techniques such as hydraulic backfilling, fly ash injection, pneumatic filling, and blasting are discussed.

SUBSIDENCE REFERENCES NOT AVAILABLE AT DRCOG

Site Investigations in Areas of Subsidence, by Newnes-Butterworths, London, England, 1975.

Subsidence Due to Underground Mining (In Two Parts)

1. Theory and Practices in Predicting Surface Deformation

2. Ground Movements and Mining Damage

by Gerhard Brauner, Denver Mining Research Center, Denver, Colorado, U.S. Bureau of Mines Information Circular 8571.

Part 1 reviews the methods of predicting mine subsidence which are used mainly in European coalfields. Part 2 deals with the practical implications of ground movements which affect mining shafts and surface structures.

SUBSIDENCE MAPS

Ground Subsidence and Land Use Considerations Over Coal Mines in the Boulder-Weld Coal Field, by Amuedo and Ivey, Geological Consultants for the Colorado Geological Survey, 1975, Environmental Geology #9, Scale 1:24,000.

Plate 1	Extent of Mining
Plate 2	Depth of Cover
Plate 3	Mine Pillars
Plate 4	Probable Thickness of Extracted Coal
Plate 5	Subsidence Inventory
Plate 6	Subsidence Hazard

Map Showing Earth Materials that may Compact and Cause Settlement in the Golden Quadrangle, Jefferson County, Colorado, by Howard E. Simpson, U.S. Geological Survey, Map I-761-D, published in 1973, Scale 1:24,000.

Map of Deposits Especially Susceptible to Compaction or Subsidence, Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, U.S. Geological Survey, published in 1972, Map I-770-J, Scale 1:24,000.

Engineering Soils Map, Geologic Aspects, Soils and Related Foundation Problems - Denver Metropolitan Area, Adams, Arapahoe, Denver and Jefferson Counties, prepared for CGS by Willard Owens Associates, 1972, Scale - approximately 1:75,000.

This map shows loess and river clay as settling soils.

Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado, by Maxwell E. Gardner, Howard E. Simpson, and Stephen S. Hart, U.S. Geological Survey, Front Frange Urban Corridor, Colorado, Environmental Geologic and Hydrologic Studies, MF-308, published in 1971, Scale 1:24,000.

Coal Mines of Colorado - Jefferson County, prepared by the Colorado School of Mines Foundation, Inc., 1964, Scale 1" = 1 Mile.

Engineering Geology and Mineral Resources Colorado Technological Center, Louisville, Colorado, by Charles S. Robinson and Associates, June 1976, Subsidence Potential Map of Colorado Technological Center, Louisville, Colorado (Figure 3), Scale 1" = 200 Feet, 1:2400.

Mined Areas of Boulder-Weld Coalfield, Scale 1:24,000, Source data - U.S. Bureau of Mines report, "Analysis of the Boulder-Weld Coalfield, Colorado," by Raymond Lowrie, 1966.

Map Showing Mined Areas of the Boulder-Weld Coalfield, Colorado, U.S.G.S. Front Range Urban Corridor, Colorado Environmental Geologic and Hydrologic Studies MF-513, by Roger B. Colton, U.S.G.S. and Raymond Lowrie, U.S. Bureau of Mines, Scale 1:48,000.

Geologic Map of the Lafayette Quadrangle, Adams Boulder and Jefferson Counties, Colorado, by Michael N. Machette, U.S. Geological Survey, 1975, Scale 1:24,000.

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SHRINK-SWELL SOIL

Criteria for Specification:

Those land areas in the Front Range urban corridor[1] with soil and bedrock which have been identified as having a "very high swell potential" or a "high swell potential", and those soils east of the Front Range urban corridor (the plains in eastern Adams and Arapahoe Counties) which have been identified as having a "high shrink-swell potential" are designated as environmentally significant hazard areas in the Denver Region.

Basis for Criteria:

Swelling soils are those soils that may increase and decrease in volume as the moisture content of the soil is varied. Diverse natural material such as pyrites, white alkali (sodium sulphate) and many clays can cause shrink-swell volume changes in soil. In the Denver region, most swelling of soil is caused by clay containing the mineral montmorillonite. The amount of swelling in a clay soil basically depends upon its mineral composition, its moisture change and its density. Swell capacity can also be affected by the cation exhange of water permeating through the clay soil.

The actual swelling of soil is caused by expansion of the clay lattice structure due to wetting of clay minerals in rocks and dry soil. Common clay minerals in the State of Colorado are montmorillonite, illite and kaolinite. Clay minerals tend to expand because of a chemical attraction of water to them. Montmorillonite clay minerals are composed of microscopic flat clay plates. Water is adsorbed in layers between the flat clay plates. As more and more water is attracted and accumulates between the clay plates, they are pushed farther and farther apart causing a greater swelling of the clay. This swelling increases soil volume and creates high swelling pressures which in turn may cause damage to streets and structures. When a wet swelling clay is dried out, the opposite result, shrinkage, will occur. Although no large pressure is associated with soil shrinkage, a significant decrease in soil volume will occur and the cracking of structures can result.

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[1] The Front Range Urban Corridor includes the foothills and piedmont area of Colorado from Ft. Collins and Greeley on the north to Pueblo and Canon City on the south.

The swell potential of soil is also affected by load removal. Montmorillonite clay soils, even when saturated, can swell if the load is removed. An example in the Denver Region of swelling due to load removal is swelling of the subgrade of the Boulder Turnpike near Boulder.

Land areas with soils which have a "very high swell potential" and a "high swell potential" have been designated as environmental hazard areas in the Front Range urban corridor of the Denver Region because soils of these two classifications can cause the most severe damage to structures built in or upon this soil when they swell. Areas of high and very high soil swell potential were delineated in a special study prepared in 1974 by the Colorado Geological Survey (CGS).[2] This study was prepared to identify areas of swelling soil as mandated under HB·1041. Soils were designated under five classifications of swell potential based upon the average swell capability for the upper 10 feet of soil and bedrock. These classifications are generally described in Table 1.

The data used by the Colorado Geological Survey (CGS) to classify soils in different swell potential categories was obtained from a variety of scientifically established testing methods and sources. Each of these tests and sources measured factors which affect the swelling potential of soil. The factors which affect the potential volume change (swelling or shrinking) of soil are as follows:[3]

1. Clay Mineralogy

   The amount of expansion of a soil is affected by such characteristics of the clay mineralogy as the type of clay minerals, the amount of clay minerals, the cation exchange capacity and the clay particle size.

2. Density

   Since there are a greater number of clay particles per unit volume in a dense soil than in a loosely compacted soil, a greater amount of swell is possible in the dense soil.

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[2] Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado Environmental Geology Report #7, by Stephen Hart, Colorado Geological Survey, 1974.

[3] CGS Environmental Geology Report #7, Appendix C (Holtz, 1959; Johnson, 1969; Lambe and Whitman, 1959)

TABLE 1

CLASSIFICATIONS OF SOIL SWELL POTENTIAL

Shrink/Swell Potential	Description
Very High Swell Potential	This category includes only bedrock or weathered bedrock. The precautions listed below under "high swell potential" must be utilized. Although construction in these areas is often unavoidable, alternate non-construction (non-structural) uses might be considered for such areas.
High Swell Potential	This category generally includes only bedrock and colluvium. Careful site investigation, special foundation design, and proper post-construction landscaping and maintenance are required to prevent or minimize damage.
Moderate Swell Potential	This category includes several bedrock formations and a few surficial deposits of variable thickness. Special foundation designs are generally necessary to prevent damange.
Low Swell Potential	This category includes several bedrock formations and many surficial deposits. The thickness of the surficial deposits may be variable, therefore bedrock with a higher swell potential may locally be less than 10 feet below the surface.
Windblown Sand or Silt	Although this material generally has low swell potential, the upper 6 inches to 12 inches may locally have moderate swell potential. Windblown material may be subject to severe settlement or

TABLE 1 (cont'd)

Shrink/Swell Potential		Description
Windblown Sand or Silt (cont'd)	-	hydrocompaction when water is allowed to saturate the deposits. The thickness of windblown material may be very variable, therefore bedrock with higher swell potential may locally be less than 10 feet below the surface.

Source: Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado, Environmental Geology Report #7, by Stephen Hart, Colorado Geological Survey, 1974.

3. Moisture Content

Clay of a low moisture content has a greater swell potential than does wet clay because drier clay has a greater capacity for adsorbing water. This water is adsorbed in layers between the clay lattices of the dry clay.

4. Soil Structure

Remolded clays will swell up to two or more times more than undisturbed clays under similar moisture change conditions. This occurs because the clay platelets of the remolded clays are already in a preferred orientation for accepting moisture.

5. Time

Soils of high plasticity have low permeabilities and often become self-sealing when they are wet. Consequently, it may take weeks or even years for these clays to become saturated. Lower plasticity clays, having greater permeability, can absorb water more rapidly, and consequently swell more rapidly.

6. Pore Fluid

The presence of salts such as calcium or sodium carbonate, or calcium sulfate or other salts in the pore fluid may lower the amount of water adsorption between the clay plates in the soil structure. Consequently, with lower water adsorption there is a lesser amount of soil swell.

7. Loading Conditions

The pressure (weight per unit area) of a structure built on swelling clay will generally determine the amount that soil can swell. If a building is erected such that the structural pressure on swelling soil is equal to the internal swelling pressure of the soil, then the soil's volume change could be held to zero. Removal of load, however, can cause expansion to occur even in saturated soils.

Established scientific index and design tests were used to analyze the soils in this region. Index tests analyze such characteristics as moisture content, shrinkage limits, plastic limit, liquid limit, grain size, and dry density. Index tests are generally rapid, simple and inexpensive tests used to give a general picture of certain soil characteristics and are often used as a guide for initial analysis.

Design tests are more complicated and expensive, but they are the only tests that can be relied on for building design purposes. The consolidation swell test is basically the only design test used for swelling soils and it provides data enabling one to estimate the bearing capacity of the soil. This information can enable engineers to design structures with a loading capacity sufficient to prevent excess swell and to know what weight of structure a soil can support before that structure will penetrate through the soil into bedrock, overburden soils, or fills. For these tests to be applicable for structural design purposes, it is important that future environmental conditions be visualized and duplicated during the tests.

Index classification systems which use several index tests have been derived to attempt to approximate the results of the consolidation swell design test. Index classification systems that were run on many soil samples in the Front Range Urban Corridor were the Chen Classification, the Seed-Woodward-Lundgren Classification, the Holtz-Gibbs Classification and several other less popular test classifications.[4] The Holtz-Gibbs classification was developed by the Bureau of Reclamation in Denver in the early 1950's. This system more nearly approximated the results of the consolidation-swell design test in the Front Range urban corridor testing than did any other index classification system and was consequently one of the more useful classification systems.[5] Most of these classification systems relied on index tests of plastic, liquid, and shrinkage limits and grain size.

Index test data was obtained for approximately 3000 soil test sites in the Front Range Urban Corridor study area. 2000 of these soil core samples were obtained from the Colorado Division of Highways and additional soil borings and test data were collected from the U.S. Geological Survey, the Colorado Geological Survey and from numerous engineering and architectural consulting firms in the region. The locations of all the soil borings were plotted on maps and the results of the soil tests were correlated to these locations so that areas of differing swell potential could be generally designated. This data was then correlated to the boundaries of geological formations as designated on detailed geologic maps of the region. The bedrock units underlying potential shrink-swell soil hazard areas in the urban corridor area are Pierre Shale, Laramie Formation, Dawson and Denver - Arapahoe Formation and some surficial geologic units such as loess, colluvium, residium, and some alluvium. Mapped boundaries of these geologic units in many cases were used to designate the boundaries between varying categories of swelling soil.

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[4] For further information on these classification systems, consult CGS Environmental Geology Report #7 - Appendix D.

[5] CGS Environmental Geology Report #7, Page 23.

The Colorado Geological Survey study of swelling soil only covered the area defined as the Front Range Urban Corridor. This area does not include the eastern plains area of the region. Shrink swell data for the eastern plains area was obtained from a statewide study of shrink-swell soil which was completed in 1974 by the Colorado Land Use Commission. This study was of a much more general nature and was not based upon the numerous test data from soil borings which was used in the Front Range Urban Corridor Study. The Colorado Land Use Commission study used information obtained directly from published U.S. Department of Agriculture Soil Conservation Service County Soil Surveys. Those soils which were designated as having a high shrink-swell potential causing severe limitations for use as foundations for low buildings or for highway construction in the County Soil Surveys were used to designate shrink-swell hazard areas in the statewide Land Use Commission study. The shrink swell ratings in that study generally refer to the average of the top five feet of soil.[6]

Swelling soil is an environmental hazard because of the damage that it can cause to improperly loaded structures placed upon it. Swelling clay creates pressures which can result in shifting foundations, uplifting of floors and roofs from their supporting columns, and cracked walls, floors, ceilings, doors and windows. Damage to buildings has also occurred as a result of using compacted fills which contain expansive clays. Some of the bad examples of swell damage in the Denver Region are those of structures built on expansive fills.

Each year shrinking or swelling soils cause at least $2.3 billion in damages to buildings, roads, and pipelines throughout the nation. This figure is more than twice the total damage caused by floods, hurricanes, tornadoes and earthquakes in the United States each year![7] Of this $2.3 billion damage, $1.14 billion, or half of the total damage is caused to highways and streets. This damage represents a public loss and consequently the cost of repairs and reconstruction is borne by all taxpayers.

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[6] Conversation with Clayton Spears, U.S.D.A. Soil Conservation Service, author of the Land Use Commission statewide Shrink-Swell Soil Map.

7 "Expansive Soils - the Hidden Disaster" by D. Earl Jones and Wesley G. Holtz; "Civil Engineering" - American Society of Civil Engineers, August 1973.

Swelling soils are found in every state in the nation and cover almost one-fourth of the nation's total land. More than 250,000 new homes are constructed on these swelling soils each year. Of these new homes, 60% will experience only minor damage during their lifetime, but 10% will experience very significant damage -- some beyond repair.[8]

Much evidence of building damage from swelling soil is apparent in the Denver region. In public buildings such as schools and in residences, damage has been in the form of cracked walls, ceilings, floors, doors and windows. Floors and walls have pulled away from support columns and prestress concrete panels have warped and bowed. Swelling clay has also caused severe damage to roads in this region and heaved and cracked city streets, sidewalks, driveways and patio slabs are all common examples of damage from swelling soil within the Denver Region.

Swelling soils are one of the most widespread and significant geologic hazards in the Denver Region. In this region, bedrock formations with swell potential underlie most of the urbanized area. Rocks containing swelling clay generally occur on the plains and valleys rather than in the high mountain areas. The soils which formed from the bedrock in the mountains in western Jefferson and Boulder Counties are generally sandy and not clay-like. Consequently, in the Denver Region, the swelling soil problem is found to the east of the mountains. The majority of Colorado's population, however, is concentrated in the valleys rather than the high mountain areas, and consequently, many homes, public buildings, churches, businesses, other structures, and roads are located in areas with a greater potential for swelling soil problems.

The state of the art of methods for controlling expansion of clay is such that damage from swelling soil can be eliminated or held to a very minor amount. However, the cost of full preventative measures may be excessive in terms of the value of the structure or the ability of the landowner to pay. Other procedures are often used to mitigate some of the problems of swelling soil. These include special considerations in foundation design, site drainage, site landscaping, interior construction and preparation of the site prior to and during construction. Keeping the soil and foundation dry during construction will eliminate some problems, but this procedure is very impractical because of rainfall and leakage. It is very important to set up a suitable surface and subsurface drainage system to keep runoff and other water away from the structure's foundation. Additional moisture near the building's foundation can only cause increased swell potential. Application of lime (CaO) or cement to the soil has proven very effective in many cases for mitigation of soil swell. However, the lime must be thoroughly mixed with the clay to be effective and it is a relatively costly procedure except for large projects.

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[8] Ibid.

Each particular location of swelling soil is a unique situation with its own unique characteristics. For this reason, it is imperative that each potential construction site be carefully inspected and analyzed by qualified soil engineers to determine the swell potential of the soil on that site and to determine which mitigation procedures would be most appropriate and effective for the specified site.

MAPPING STUDIES USED IN DESIGNATING SHRINK-SWELL SOILS

Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado
by Stephen S. Hart
Colorado Geological Survey, 1974
Greater Denver Area, Colorado
Boulder-Fort Collins-Greeley Area, Colorado
Scale 1:100,000

Soil Shrink-Swell Potential, Colorado, 1974
Colorado Land Use Commission
Scale 1:500,000

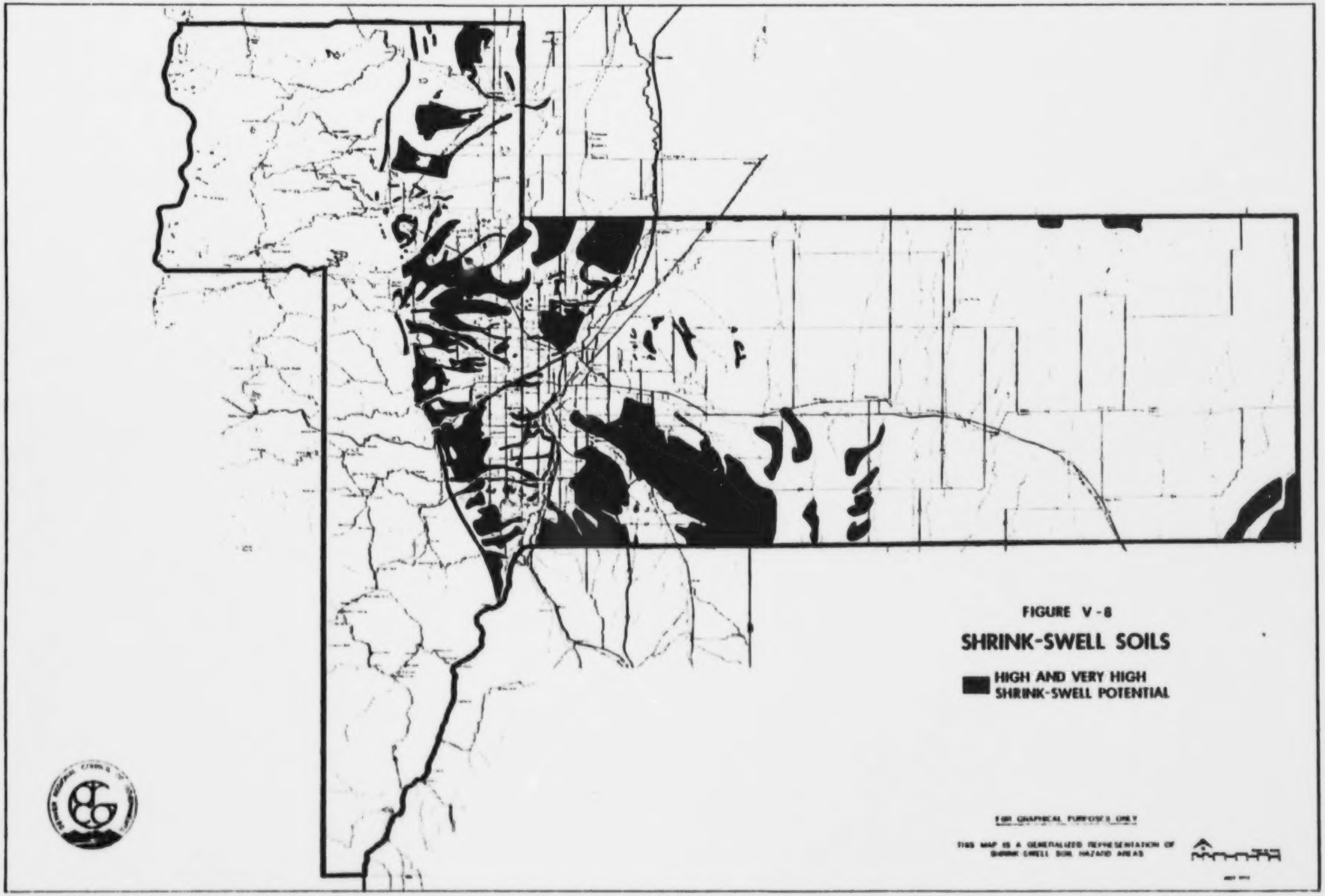

FIGURE V-8

SHRINK-SWELL SOILS

▇ HIGH AND VERY HIGH SHRINK-SWELL POTENTIAL

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF SHRINK-SWELL SOIL HAZARD AREAS

BIBLIOGRAPHY FOR SHRINK-SWELL SOILS

Sources Available at DRCOG

SHRINK-SWELL SOILS REFERENCES

Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado - Environmental Geology Report No. 7 by Stephen S. Hart, Colorado Geological Survey, Department of Natural Resources, State of Colorado, 1974.

This report is a comprehensive discussion of swelling soil in the Front Range urban corridor. It discusses how clay swells, the damage it does, hazard areas in the region and what can be done to minimize the damage from swelling soil. It also includes maps showing potential swell areas in the Front Range urban corridor.

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas - Special Publication No. 6 by W.P. Rogers, L.R. Ladwig, A.L. Hornbaker, S.D. Schwochow, S.S. Hart, D.C. Shelton, D.L. Scroggs and J.M. Soule; Colorado Geological Survey, Department of Natural Resources, 1974.

This report was prepared for the Colorado Land Use Commission for the 1041 program. It contains a good section on the hazard of swelling soils.

"Expansive Soils - The Hidden Disaster" by D. Earl Jones, Jr. and Wesley G. Holtz in "Civil Engineering" - August, 1973.

This article emphasizes the effects of damage from swelling soils throughout the nation. It discusses the varying levels of damage that happen to many different structures on swelling soil.

"The Expansive Soil Problem" by D. Earl Jones, Jr. DHUD, paper prepared for symposium on Expansive Soils, Geological Society of America, Denver, Colorado. November 9, 1976.

This paper defines expansive soils, explains ways to identify expansive soils by visual inspection and by laboratory tests, and discusses factors which affect a soils expansive behavior. It includes data on the estimates of annual damages from swelling soil throughout the nation.

"Geologic Aspects, Soils and Related Foundation Problems, Denver Metropolitan Area, Colorado", Environmental Geology #1, by Judith L. Hamilton and Willard G. Owens, prepared for the Colorado Geological Survey, Department of Natural Resources State of Colorado, 1972.

This report discusses the reasons for swelling clay and includes maps showing swelling soils in the Denver metropolitan study area. It also includes information on the types of foundation treatment and design to help alleviate swelling soil problems.

"Development Criteria to Keep Impact Within Acceptable Levels", Technical Memorandum 3-2 Resource Planning Associates, Inc., Cambridge, Mass. March 19, 1976.

This memorandum briefly describes swelling soil and its general location in the Denver region. It also recommends several development restrictions for hazardous shrink-swell soil areas.

SHRINK-SWELL SOILS MAPS

Potentially Swelling Soil and Rock in the Front Range Urban Corridor, Colorado
by Stephen S. Hart
Colorado Geological Survey, 1974
Scale - 1:100,000
Set of 4 maps

Expansive Soils - Geological Hazard Areas
Arapahoe County Planning Department
Scale - 1:24,000
Set of 2 maps

Swelling Soils
Jefferson County Planning Department
Scale - 1:24,000

Soil Shrink-Swell Potential
Colorado Land Use Commission, 1974
Scale - 1:500,000 (statewide map)

Map Showing Areas Containing Swelling Clay in the Morrison
Quadrangle, Jefferson County, Colorado, by Glenn R. Scott, 1972
U.S. Geological Survey
Scale - 1:24,000

Map Showing Relative Swelling-Pressure Potential of Geologic Materials in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, 1972
U.S. Geological Survey
Scale - 1:24,000

Engineering Soils Map - Geologic Aspects, Soils and Related Foundation Problems, Denver Metropolitan Area by Willard Owens Associates for Colorado Geological Survey, 1972.
This map shows swelling clay, residual soils and swelling soils with thin gravel cap.
Scale - Approximately 1:72,000

Swell Potential Map, Aurora, Colorado
by Brant A. Dennis, 1975
Scale - 1:24,000

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FAULTS

Criteria for Specification:

Known faults in the region, and specifically those faults which have been identified as "active" or "potentially active" as mapped and identified by the U.S. Geological Survey (U.S.G.S.) and the Colorado Geological Survey (C.G.S.) have been designated as environmentally significant areas in the Denver Region.[1]

Basis for Criteria:

A fault is a rock fracture along which rock blocks have moved past one another as a result of stresses and movement in the earth's crust. Faults are basically classified on the basis of the direction in which the rock masses move past each other along the fault plane. These movements range from a fraction of an inch to hundreds of miles.

Sudden movement along a fault will cause an earthquake and consequently faults can be classified as potential geologic hazard areas. Earthquakes cause damage resulting from severe ground shaking and surface rupture and from secondary earthquake effects such as landsliding, differential settlement, and dam failure.

The recorded earthquake history of Colorado has been relatively quiet. The first reported earthquake in Colorado was in the year 1870 and since that time only a few earthquakes have exceeded a magnitude of 5.0 on the Richter scale.[2] Shock waves with a Richter value of less than 5.0 are local in their effects and do little damage. Shocks ranging between 5.0 and 7.0 are moderately intense and can seriously damage certain types of man-made structures. Any seismic shock of 7.0 or above is considered a major earthquake which causes great destruction. This past record of a relatively quiet earthquake history in Colorado does not necessarily indicate that future earthquake activity in the State will continue to be quiet.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

[2] Personal communication with Robert Kirkham, Engineering Geologist, Colorado Geological Survey, September 1977.

A better source than past earthquake records for providing information about the location and frequency of expectable large earthquakes is recent geologic history, especially the history of recent movements on faults or in fault systems. Seismotectonic relationships in California and Nevada indicate a direct correlation between large earthquakes and active faults.[3] Determination of the potential of future earthquakes along faults is an exceedingly complex procedure which must incorporate knowledge of the occurrence of historic earthquakes and geologic history of recent fault activity. Analysis of the recent history of any fault can only be accomplished through detailed geological investigations, surface mapping, and trench and drill-hole interpretations.

Generally, an earthquake occurs when stresses acting on a rock mass exceed the rock shear strength causing failure along a fault plane and the release of energy. The location where the movement or energy release initiates is the earthquake focus or hypocenter and the point on the earth surface vertically above the hypocenter is called the epicenter.[4] As the fault breaks and moves, energy is released in the form of seismic waves moving outward in all directions from the hypocenter. These waves cause the ground shaking experienced during an earthquake which in turn often causes significant damage.

Displacement along a fault which results from large earthquakes usually causes surface rupture, however, the displacement that takes place along faults resulting from small earthquakes is oftentimes not seen at the earth's surface. In many earthquakes throughout the world each year, rupture of rock masses occurs without visibily disturbing the earth's surface. Even in instances where the surface has been displaced during an earthquake, erosion will very often wear away the evidence of the displacement. Geologists must, however, look at any evidence of surface rupture to really understand the recent history of movement.

Records of the movement of earth masses by faulting are preserved in rock layers beneath the earth's surface. Excavation of the earth's surface for extraction of minerals, for road construction, or for other reasons will oftentimes expose records of earth movement due to faulting. A bed of coal, for example, may extend for many miles and then be abruptly cut off due to faulting of the beds.

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[3] Personal communication with Robert Kirkham, Engineering Geologist, Colorado Geological Survey, September 1977.

[4] _Ibid_.

Faults can be recognized in many ways. If the fault is exposed in a roadcut, a cliff, or a mine excavation, it can be easily observed because of the discontinuity of structure, repetition or omission of strata. If this direct evidence is not present, one must rely upon physiographic criteria observed both in the field and on remotely sensed imagery to detect and locate faults.

The age of fault movement can be established by relationships between the fault and the deposits along it. If the fault displaces the deposit, the fault movement is younger than the age of the deposits. If the fault is covered by the deposit then the movement is older than the overlying deposit. The age of the most recent movement on a fault is between the ages of the youngest deposit offset by the fault and the oldest deposit which covers the fault.

Thousands of faults occur in the Denver Region. These faults are located in the western part of the region in Boulder and Jefferson Counties. The formation of the faults in this region is related to the geologic history of mountain building. The State of Colorado experienced multiple periods of mountain building and subsequent erosion during which the mountains were totally removed. The present mountains known as the Colorado Front Range were uplifted in the Miocene period approximately 25 million years ago and it is believed that these mountain building processes are continuing today.[5] The faults in the Front Range trend northwest and northeast and extend along the mountain-front and eastward for a distance of two to three miles.

The faulting along north-to-west trends occurred at various times over a period ranging from about 1,700 million years ago to Late Cretaceous or early Tertiary time (60-120 million years ago). During the Late Cretaceous to early Tertiary time the older basement rocks and the younger sedimentary rocks along the Front Range of the Rockies were upturned and faulted by renewed movements along the existing northwest--trending fault systems.[6]

As indicated previously, there are thousands of faults throughout the Front Range and in the Denver Region. Of all these faults, however, only a few have been identified as being "active" or "potentially active."

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[5] Personal communication with Robert Kirkham, Engineering Geologist, Colorado Geological Survey, September 1977.

[6] Geology and Uranium Deposits of the Ralston Buttes District, Jefferson County, Colorado, by Douglas M. Sheridan, Charles H. Maxwell, Arden L. Albee, and Richard Van Horn, 1967. U.S. Geological Survey Professional Paper 520.

An "active" fault has been defined for the purposes of this study as one which has shown displacement within the Quaternary period (approximately the last one to two million years) and a "potentially active" fault is one that has shown displacement since the Miocene period (approximately the last 25 million years--see Figure 1).[7] Studies by the U.S. Geological Survey in 1970[8] and the Colorado Geological Survey in 1977[9] have identified these faults. The identified "active" faults in the Denver Region are the Golden fault, the Valmont fault, and the Rocky Mountain Arsenal Fault. The identified "potentially active" faults in the region are the Floyd Hill fault and the Kennedy Gulch fault.

In 1970, the U.S. Geological Survey (USGS) conducted a study of Quaternary faulting and earthquake potential in east-central Colorado. Results of this study revealed that eight faults in east-central Colorado had shifted at times ranging from more than one million years ago to as recent as 10,000 years ago.[10] Additional studies indicate that some faults may have shifted even more recently. This USGS study discusses the amount and direction of displacement along the faults, the geologic setting, and estimates of the time of the most recent movement.

No measurable displacement is known to have occurred along the faults in this region for past recorded history which is about 120 years. The Rocky Mountain Arsenal Fault is thought to have had movement during this time period; however, that movement didn't result in any surface displacement. Geologic evidence does indicate that three faults in the region have moved within the Yarmouth age (Figure 1) or approximately the past 600,000 years.[11] These are basically the most recent known fault displacements in the Denver region. The faults which

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[7] Personal communication with Robert Kirkham, Colorado Geological Survey, September 1977.

[8] "Quaternary Faulting and Potential Earthquakes in East-Central Colorado," by Glenn R. Scott, 1970, U.S. Geological Survey Professional Paper 700-C.

[9] Unpublished study on "Earthquake Potential in Colorado" for the Colorado Geological Survey by Robert Kirkham, 1976/1977.

[10] "Quaternary Faulting and Potential Earthquakes in East-Central Colorado," by Glenn R. Scott, 1970, U.S. Geological Survey Professional Paper 700-C.

[11] Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado by Maxwell E. Gardner, Howard E. Simpson and Stephen S. Hart, U.S. Geological Survey, MF-308, 1971.

Figure 1

MAJOR QUATERNARY AND TERTIARY GEOLOGIC TIME SUBDIVISIONS

Time				Approximate Years Before Present
Era	System or Period	Series or Epoch	Glacial and Inter-Glacial Periods	
Cenozoic	Quaternary	Holocene	Post-Pinedale	0
				10,000
		Pleistocene	Pinedale	
			Bull Lake	
				130,000
			Sangamon or Illinoian	
			Yarmouth or Kansan	
			Aftonian or Nebraskan	
				1-2 million
	Tertiary	Pliocene		
				10 million
		Miocene		
				25 million
		Oligocene		
				40 million
		Eocene		
				60 million
		Paleocene		

have shown this recent displacement and are identified as "active" faults are the Golden fault, the Valmont fault, and the Rocky Mountain Arsenal fault.

The Golden fault extends along the general area of the foothills and hogback from slightly south of Morrison, north through Golden on to the area around Rocky Flats in northern Jefferson County. The Golden fault zone is about 20 miles long and up to 3,000 feet wide in some areas and is part of a structural zone that bounds the east flank of the Front Range, Colorado. The Golden fault is classified as a compressional or high angle reverse fault because the rock formations on the west side of the fault are displaced upward and eastward with respect to the rock formations on the eastward side.[12]

The Golden fault trends northward, dips steeply west, and in some places exhibits greater than 8,000 feet of uplift, or vertical throw. Recent trench excavations through a portion of the fault zone near the City of Golden, Colorado reveal a minimum of two periods of fault rupture or movement with a total of 18 feet of vertical displacement since the Yarmouth period (Figure 1) or approximately the past 600,000-700,000 years.[13] At no place along the entire length of the Golden fault is there any known surficial evidence of movement within the Quaternary period except in the exploratory trench described by the U.S. Geological Survey in 1970 and reevaluated by the Colorado Geological Survey in 1977.

Geophysical information suggests that the Golden fault is still active. Seismic data for the area of the Golden fault attributed 31 earthquakes with a magnitude of less than 4.0 to activity on the Golden fault in 1967,[14] plus six additional small earthquakes in 1976.[15] However, none of these events caused significant known damage.

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[12] "Geologic Aspects, Soils and Related Foundation Problems, Denver Metropolitan Area, Colorado," by Judith L. Hamilton, and Willard G. Owens, 1972, prepared for the Colorado Geological Survey, Environmental Geology Report No. 1.

[13] "Quaternary Movements on the Golden Fault, Colorado, by Robert M. Kirkham, Colorado Geological Survey, 1977.

[14] "Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado," by Maxwell E. Gardner, Howard E. Simpson and Stephen S. Hart, U.S. Geological Survey, 1971.

[15] Personal communication with Robert Kirkham, Engineering Geologist, Colorado Geological Survey, September 1977.

The Valmont fault is a minor vertical fault which trends northeast/southwest for a distance of less than one mile near Valmont in Boulder County. Specifically, it is located in Section 24, TIN, R70W. The fault movement displaced recent alluvial deposits on the south downward against Fox Hills sandstone on the north. The total displacement is approximately five feet and is estimated to be of Sangamon or Illinoian age (Figure 1). There is no obvious surficial expression of this fault and it is known only because of its exposure in a roadcut. A zone of sheared and disrupted Fox Hills Sandstone marks the fault trace in the bedrock, and gravel deposits in overlying alluvium are disoriented. Numerous faults cut through the Boulder-Weld coalfield in southeastern Boulder County and southwestern Weld County. The Valmont fault is in the midst of all these faults and it is the only fault for which displacement is documented.

The third fault identified as active is the Rocky Mountain Arsenal fault. There is no surface expression of this fault and its existence has not been thoroughly documented. However, the distribution of the epicenters of the earthquakes which occurred at the Rocky Mountain Arsenal in the early 1960's line up along a trend. This trend may suggest a possible fault at depth.[16]

The 1970 USGS (Scott) study on faulting and earthquakes in east-central Colorado identified an active fault near Morrison, Colorado. More recent studies have, howaver, provided additional information to indicate that this feature is not a potential hazard.

The faults which have been identified as "potentially active" are the Floyd Hill fault and the Kennedy Gulch fault. The Floyd Hill fault is about 25 miles long and trends northwest. It is located in Jefferson County and extends from near Bergen Park southeast to the general area around Phillipsburg. This fault shows about 700 feet of displacement since the Miocene period (approximately the last 25 million years).

Miocene movement on the Kennedy Gulch fault has been estimated at about 1,000 feet. This amount of movement is evidenced by displacement of Tertiary gravel deposits.

Quaternary fault displacement generally indicates the probable occurrence of large earthquakes. Quaternary displacement can usually be identified by the offset of uncolsolidated surficial deposits across faults.[17] The displacements in the surficial deposits were caused by movements along deep faults. Such comparable fault movement today could result in earthquakes. U.S. Geological Survey and Colorado Geological Survey research has indicated that future displacement along some of the faults in the Denver Region could result in strong enough earthquakes to endanger people and property. The magnitude of earthquakes can be predicted from data on fault characteristics such as length of the fault and the amount of displacement. These characteristics of the Golden fault indicate that the magnitude of a future earthquake along that fault would be from 6.5-7.7 on the Richter scale.[18]

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[16] Personal communication with Robert Kirkham, Engineering Geologist, Colorado Geological Survey, September 1977.

[17] "Quaternary Faulting and Potential Earthquakes in East-Central Colorado," by Glenn R. Scott, 1970, U.S. Geological Survey Professional Paper 700-C.

In past history, earthquakes in Colorado have caused only minor rockslides and damage to structures. However, the existence of Quaternary displacement shows that there have been high-magnitude earthquakes in Colorado in Quaternary time because a magnitude of about 6.0-6.5 on the Richter Scale is generally necessary to cause surface ruptures as can be seen along the Golden fault and the Valmont fault. The magnitude of earthquake necessary to cause surface rupture depends on the depth of focus, the character of the ruptured material and other factors.[19] The intensity of shaking caused by an earthquake is the most important factor to consider in structural design and that depends on magnitude, depth of focus and attenuation characteristics.

Evidence for faulting is indirect in some parts of the region and consists of repetition of beds, overturning, and apparent offset of beds across covered areas. In many places in the region, faults contain breccia (crushed, angular rock), gouge (clay and finely divided rock fragments), or cemented breccia and gouge. These crushed rock materials in the faults are sometimes excavated and used for construction materials.

Many of the fault zones along the Front Range contain minerals. Deposits of uranium, fluorite and lead, copper and zinc sulfides have been found along some of the fault zones around Evergreen and nearby areas. The uranium was deposited along faults in the Precambrian rocks during the time when many of the faults were formed 60 to 120 million years ago.[20]

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[18] Faults and Earthquake Magnitude, by David Slemmons, U.S. Army Corps of Engineers Miscellaneous Paper S-73-1, Report 6, May 1977.

[19] "Quaternary Faulting and Potential Earthquakes in East-Central Colorado," by Glenn R. Scott, 1970, U.S. Geological Survey Professional Paper 700-C.

[20] Geology and Uranium Deposits of the Ralston Buttes District, Jefferson County, Colorado, U.S. Geological Survey Professional Paper 520, by Douglas M. Sheridan, Charles H. Maxwell, Arden L. Albee and Richard Van Horn, 1967.

Faults are important environmental characteristics in this region not only because of the potential for earthquakes resulting from displacement along faults, but because of their relationship with groundwater supply and quality. Faults, joints, and other fractures in rock material may function as conduits transporting rainfall, surface water and runoff underground to the aquifer which stores groundwater. In this way faults are very important for recharging groundwater. In fact, many developed areas in the mountains depend on infiltration of precipitation through faults to recharge the aquifer which provides their wells with water. However, this seepage through faults might also allow sewage waste or pollutants to drain through the faults or joints into pure groundwater and then pollute it. Pollution from seepage through faults is evidenced by reports of the presence of hydrogen sulfide and methane gases in the water of many wells in the northern portion of the Denver Metropolitan area,[21] and by the presence of septic leachate in wells in the mountainous portion of the region. In addition, water that percolates through the mineralized areas of faults might contain unusually high concentrations of flourine and metallic elements.

Faults in the Denver Region have been designated as environmentally significant areas for many reasons. Faults which have had recent displacement are potential environmental hazards because past recent movement along faults generally indicates the probable occurrence of future earthquakes. This hazard, as indicated earlier, is associated with several faults in the Denver Region--the Golden fault, the Valmont fault, the Rocky Mountain Arsenal fault, the Floyd Hill fault, and the Kennedy Gulch fault. Many faults in this region are relatively stable and have been so for long periods of time but there is usually a possibility that land use activity and development, or other man-induced seismicity, might effect this stability. Information that is important in evaluating the potential for future movement along faults and the resultant triggering of earthquakes are fault displacement data on the net Quaternary vertical offset, the length of the Quaternary displacement, the geologic setting, estimates of the time of the most recent movement, recurrence rates, and historic seismic records.

Inactive faults are not special earthquake hazards, however, they are often natural resource areas because of the occurrence of minerals in veins along them and because of the crushed rocks along them which can be excavated and used for construction purposes.

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[21] Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

Inactive faults have also been useful to man for many of his activities. Most of the canyons in the mountains along the South Platte River are along faults. These fault displacements are often used by man for locating roads or railroad lines to provide transportation routes, or for the location of utility lines. In addition, the canyons along faults are often used for siting recreational facilities.

Faults are also environmentally significant because of their relationship of transmitting both precipitation and contaminants into the ground water supply. Because of the effect of faults on ground water supply and quality it is very important to carefully analyze the location of faults in making decisions on locating individual water wells.

MAPPING STUDIES USED IN DESIGNATING FAULTS IN THE DENVER REGION

Map Showing Faults, Joints, Foliation, and Surficial Deposits in the Evergreen Quadrangle, Jefferson County, Colorado by John C. Reed, Jr., Douglas M. Sheridan, and Bruce Bryant, 1973. U.S. Geological Survey Map I-786-F, Scale 1:24,000.

"Bedrock Geology of the Kassler Quadrangle, Colorado" by Glenn R. Scott, Geological Survey Professional Paper 421-B, Bedrock Geologic Map and Section of the Kassler Quadrangle, Jefferson and Douglas Counties, Colorado, U.S. Geological Survey, Professional Paper 421 - Plate 2, Scale 1:24,000.

Geologic Map of the Indian Hills Quadrangle, Jefferson County, Colorado by Bruce Bryant, Robert D. Miller, and Glenn R. Scott, 1973, U.S. Geological Survey Map GQ-1073, Scale 1:24,000.

Geology and Uranium Deposits of the Ralston Buttes District Jefferson County, Colorado by Douglas M. Sheridan, Charles H. Maxwell, Arden L. Albee and Richard Van Horn, Geological Survey Professional Paper 520, Geologic Map and Sections of the Ralston Buttes District, Jefferson County, Colorado, U.S. Geological Survey Professional Paper 520 - Plate 1, Scale 1:24,000.

Geologic Map of the Lafayette Quadrangle, Adams, Boulder and Jefferson Counties, Colorado by Michael N. Machette, 1975, U.S. Geological Survey Map MF-656, Scale 1:24,000.

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Reconnaissance Geologic Map of the Conifer Quadrangle, Jefferson County, Colorado by Bruce Bryant, 1974, U.S. Geological Survey Map MF-597, Scale 1:24,000.

Reconnaissance Geologic Map of the Pine Quadrangle, Jefferson County, Colorado by Bruce Bryant, 1974, U.S. Geological Survey Map MF-598, Scale 1:24,000.

Geologic Map of the Tungsten Quadrangle, Boulder, Gilpin and Jefferson Counties, Colorado, by Dolores J. Gable, 1972, U.S. Geological Survey Map GQ-978, Scale 1:24,000.

Geologic Map of the Nederland Quadrangle, Boulder and Gilpin Counties, Colorado, by Dolores J. Gable, 1969, U.S. Geological Survey Map GQ-833, Scale 1:24,000.

Geologic Map of the Ward Quadrangle, Boulder County, Colorado, by Dolores J. Gable and Richard F. Madole, 1976, U.S. Geological Survey Map GQ-1277, Scale 1:24,000.

Geologic Map of the Black Hawk Quadrangle, Gilpin, Jefferson, and Clear Creek Counties, Colorado, by Richard B. Taylor, 1976, U.S. Geological Survey Map GQ-1248, Scale 1:24,000.

Geologic Map of the Squaw Pass Quadrangle, Clear Creek, Jefferson, and Gilpin Counties, Colorado by Douglas M. Sheridan and Sherman P. Marsh, 1976, U.S. Geological Survey Map GQ-1337, Scale 1:24,000.

Coal Mine Subsidence and Land Use for the Boulder-Weld Coalfield, Boulder and Weld Counties, Colorado, Environmental Geology No. 9 by Amuedo and Ivey Consultants for the Colorado Geological Survey, Faults are shown on the following maps (Scale 1:24,000):

Plate 1 Extent of Mining Map
Plate 2 Depth of Cover Map
Plate 3 Mine Pillars Map

Plate 4	Probable Thickness of Extracted Coal Map
Plate 5	Subsidence Inventory Map
Plate 6	Subsidence Hazard Map

"Geologic Aspects and Related Foundation Problems, Denver Metropolitan Area, Colorado" prepared by Willard Owens Associates for the Colorado Geological Survey, Environmental Geology No. 1, Geology Map and Depth to Bedrock, Scale 1:72,000.

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Plate 1	Geologic and Aeromagnetic Map of the Indian Peaks Study Area, Boulder and Grand Counties, Colorado Scale 1:48,000

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Maps for: Greater Denver Area
Boulder-Fort Collins-Greeley Area

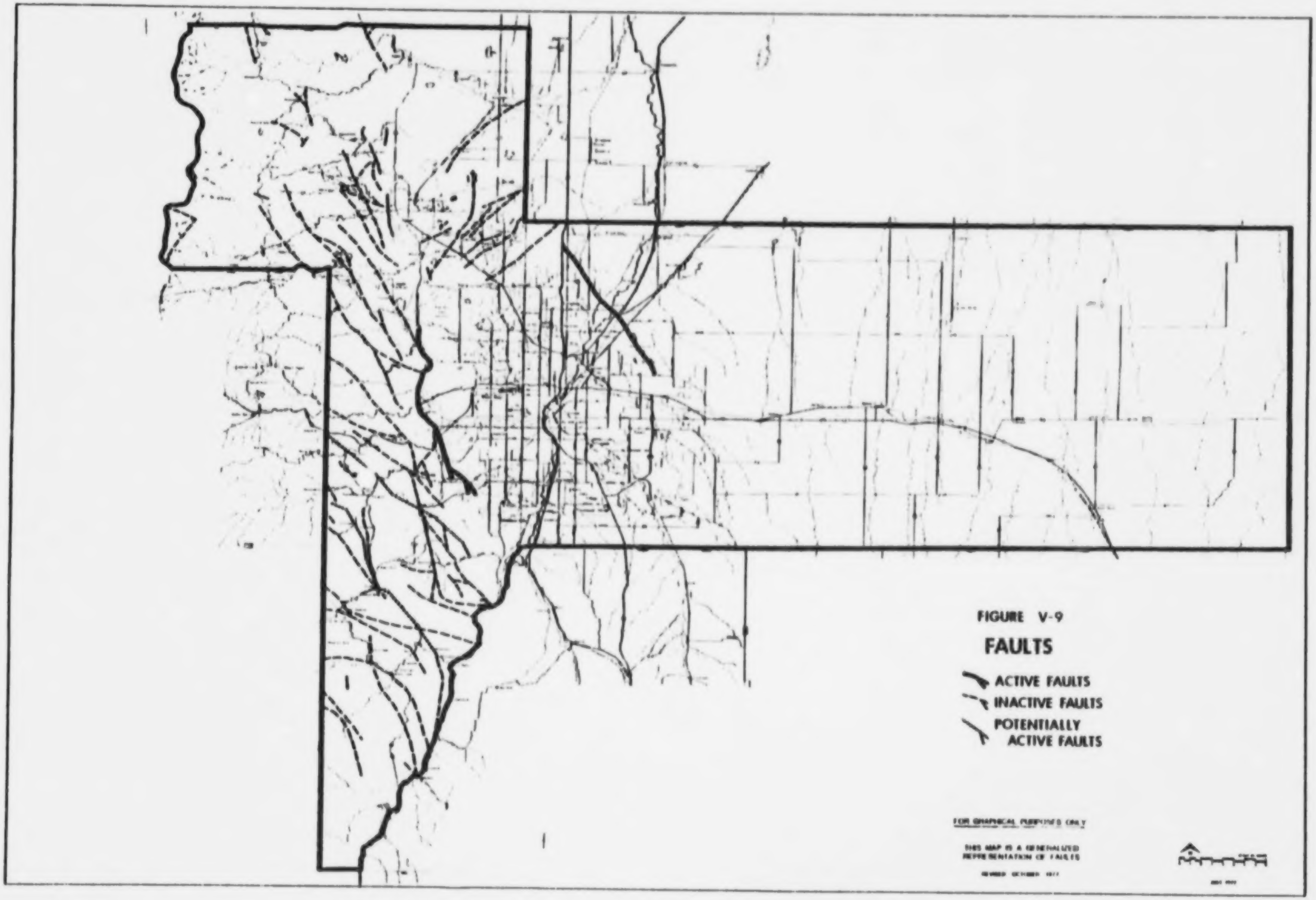

FIGURE V-9

FAULTS

ACTIVE FAULTS
INACTIVE FAULTS
POTENTIALLY ACTIVE FAULTS
FOR GRAPHICAL PURPOSES ONLY
THIS MAP IS A GENERALIZED REPRESENTATION OF FAULTS
REVISED OCTOBER 1977

BIBLIOGRAPHY FOR FAULTS

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"Quaternary Faulting and Potential Earthquakes in East-Central Colorado" by Glenn R. Scott, U.S. Geological Survey Professional Paper 700-C, Geological Survey Research 1970.

This report discusses Quaternary movement along faults in East-Central Colorado. Movement along the Golden Fault, the Valmont Fault and an unnamed fault west of Morrison are discussed.

"Geologic Aspects, Soils and Related Foundation Problems, Denver Metropolitan Area, Colorado", by Judith L. Hamilton and Willard G. Owens, 1972 prepared for the Colorado Geological Survey Environmental Geology Report No. 1.

This report discusses the Golden Fault Zone along the western portion of the Denver Region.

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas, by W.P. Rogers, L.R. Ladwig, A.L. Hornbaker, S.D. Schwochow, S.S. Hart, D.C. Shelton, D.L. Scroggs and J.M. Soule, 1974 Colorado Geological Survey, Special Publication No. 6.

This report discusses seismic effects in Colorado. Earthquake potential from man's activities such as fluid injection as well as from natural phenomenan such as movement along faults are discussed.

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This plan includes a discussion of the potential for earthquakes resulting from movement along faults in the study area.

Map Showing Faults, Joints, Foliation, and Surficial Deposits in the Evergreen Quadrangle, Jefferson County, Colorado, by John C. Reed, Jr., Douglas M. Sheridan, and Bruce Bryant, 1973, U.S. Geological Survey.

This map includes a written description of faults in the study area.

Quaternary Geology and Geomorphic History of the Kassler Quadrangle, Colorado, U.S. Geological Survey Professional Paper 421-A by Glenn R. Scott, 1963.

This report is a study of the quaternary deposits and their fossils in relation to the geomorphology of the east flank of the Front Range of the Rocky Mountains in Colorado.

Bedrock Geology of the Kassler Quadrangle, Colorado, U.S. Geological Survey Professional Paper 421-B by Glenn R. Scott, 1963.

This report is a survey of the east flank of the Colorado Front Range with emphasis on the Cretaceous rocks and on structural geology.

Geology and Uranium Deposits of the Ralston Buttes District Jefferson County, Colorado, U.S. Geological Survey Professional Paper 520 by Douglas M. Sheridan, Charles H. Maxwell, Arden L. Albee, and Richard Van Horn, 1967.

This report analyzes the geology of the study area including fault zones.

Preliminary Engineering Geologic Map of the Golden Quadrangle, Jefferson County, Colorado by Maxwell E. Gardner, Howard E. Simpson and Stephen S. Hart, 1971, U.S. Geological Survey, Front Range Urban Corridor, Colorado, Environmental Geologic and Hydrologic Studies.

This report includes a discussion of the Golden fault and other faults in the study area.

"Bedrock Geology of the Louisville Quadrangle, Colorado", by Frank D. Spencer, U.S. Geological Survey, 1961.

The text associated with the bedrock geology map discusses the faults in this quadrangle. The direction in which the faults trend, and the length, dip, and throw of the faults are discussed.

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This report discusses the geology of the study area including the predominant and minor faults.

Coal Mine Subsidence and Land Use In The Boulder-Weld Coalfield Boulder and Weld Counties, Colorado, Environmental Geology No. 9, prepared for the Colorado Geological Survey by A.R. Myers, J.B. Hansen, R.A. Lindvall, J.B. Ivey, and J.L. Hynes, March 1975.

This report discusses faulting in the area of the Boulder-Weld coalfield.

"Quaternary Movements on the Golden Fault, Colorado," by Robert M. Kirkham, Colorado Geological Survey, 1977.

This paper describes evidence of displacement along the Golden fault slightly northwest of downtown Golden. The fault displacement was evaluated on the basis of two excavations approximately 200 feet long and 33 feet deep.

"A Reappraisal of the Seismic-Risk Classification of Colorado," by Vincent Matthews in The Mountain Geologist, Volume 10, Number 4, October 1973.

This paper analyzes the Cenozoic tectonic history of Colorado and earthquake recurrence intervals throughout the world. Based on this analysis the author suggests that Colorado should revise its seismic risk classification upward and should adopt a minimum seismic design building code.

"Preliminary Investigation of Seismic Tremors in the General Area of the Leyden Coal Mine Gas-Storage Reservoir, Colorado," by Frank W. Osterwald, John B. Bennetti, Jr. and C. Richard Dunrud, U.S. Geological Survey Open-file Report, 1973.

This study investigates and monitors seismic tremors resulting from withdrawal and injection of natural gas in an old abandoned coal mine near Leyden, Colorado.

OTHER FAULT REFERENCES NOT AVAILABLE AT DRCOG

Earth and Man by Frank Byrne, 1974.

This book discusses normal faults, reverse faults, thrust faults, and transcurrent faults. Faulting near the Morrison area west of Denver, Colorado is also discussed.

A Geography of Landforms, by John H. Vann.

This book discusses the various types of faults, structures caused by faulting and physiographic features associated with faults.

Physical Geology by L. Don Leet and Sheldon Judson, 3rd Edition, 1965.

This geology textbook discusses the different types of faults and their formation.

Geophysical and Geological Studies of the Relationships Between the Denver Earthquakes and the Rocky Mountain Arsenal Well edited by John C. Hollister and Robert J. Weimer, Quarterly of the Colorado School of Mines, Volume 63, No. 1, January 1968.

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"Structural Geology of the Denver Basin - Regional Setting of the Denver Earthquakes" by John D. Haun.

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This report discusses techniques to predict earthquake magnitude based on the amount of displacement along a fault and the length of the fault.

FAULT MAPS

Map Showing Faults, Joints, Foliation, and Surficial Deposits in the Evergreen Quadrangle, Jefferson County, Colorado by John C. Reed, Jr., Douglas M. Sheridan, and Bruce Bryant, 1973. U.S. Geological Survey Map I-786-F, Scale 1:24,000

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Plate 5	Subsidence Inventory Map
Plate 6	Subsidence Hazard Map

"Geologic Aspects and Related Foundation Problems, Denver Metropolitan Area, Colorado" prepared by Willard Owens Associates for the Colorado Geological Survey, Environmental Geology No. 1, Geology Map and Depth to Bedrock, Scale 1:72,000

Generalized Surficial Geologic Map of the Denver Area, Colorado by G.H. Chase and J.A. McConaghy, U.S. Geological Survey Front Range Urban Corridor, Colorado Environmental Geologic and Hydrologic Studies, Scale 1:63,360 (1" = 1 mile)

Preliminary Geologic Map of Colorado compiled by Ogden Tweto, 1976, U.S. Geological Survey Map MF - 788, Scale 1:500,000

"Ralston Valley Comprehensive Plan" for the City of Arvada and the Ralston Valley Water and Sanitation District

Map of Seismicity and Particulate Matter
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"Mineral Resources of the Indian Peaks Study Area, Boulder and Grand Counties, Colorado," by Robert C. Pearson and Gordon Johnson, U.S. Geological Survey, and Charles Speltz, U.S. Bureau of Mines, 1975, Open-file Report 75-500,

Plate 1 - Geologic and Aeromagnetic Map of the Indian Peaks Study Area, Boulder and Grand Counties, Colorado
Scale 1:48,000

Preliminary Geologic Map - For Official Use Only
U.S. Geological Survey, 1977
Scale 1:100,000

Maps for: Greater Denver Area
Boulder-Fort Collins-Greeley Area

Preliminary Geologic Map of the Southwestern Quarter of the Denver
$1^\circ \times 2^\circ$ Quadrangle, Colorado
Compiled by Bruce Bryant and R. A. Wobus
U.S. Geological Survey, 1975
Open-file Report 75-340
Scale 1:250,000

OTHER FAULT MAPS NOT AVAILABLE AT DRCOG

Geophysical and Geological Studies of the Relationships Between the Denver Earthquake and the Rocky Mountain Arsenal Well
Part B Maps
edited by John C. Hollister and Robert J. Weimer

Quarterly of the Colorado School of Mines, Volume 63, Number 1
January 1968

Plate 1	Precambrian Geology of Mountain Front Between Turkey and Ralston Creeks Jefferson County, Colorado February 1967 Scale = 1:24,000 by L.W. LeRoy and R.J. Lickus
Plate 2	Precambrian Structure Contour Map of the Denver Basin by John D. Haun, February 1967

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SIGNIFICANT WILDLIFE HABITAT

Criteria for Specification

Areas which have been designated as "significant wildlife habitat" in the Denver Region[1] include areas defined as:

(1) High density population areas
(2) Very high density population areas
(3) Production habitat areas

A "high density population area" is a habitat area which contains a significant density of a certain designated indicator species. These densities are generally higher than the statewide average density for that species. The designated indicator species and the densities required for specification as a high density population area are listed in Table 1. Certain habitat areas identified by local county planning departments and district wildlife conservation officers of the Colorado Division of Wildlife (CDW) also have high densities of wildlife inhabiting these areas and are thusly classified as "high density population areas." These areas are also included in Table 1.

A "very high density population area" is a relatively small constricted habitat area which contains an exceedingly high density of certain designated indicator species. The designated indicator species and the densities required for specification as a very high density population area are listed in Table 2. Special habitat areas which support very high densities of one or several species of wildlife have also been identified by local county planning departments and CDW District Wildlife Conservation Officers. These areas are consequently classified as "very high density population areas" and are also listed in Table 2.

A "production area" is a habitat area used for species production activity such as fawning, calving, denning, breeding, and nesting. Production habitat areas and the species density in these habitat areas are listed in Table 3.

Basis for Criteria

Wildlife is a very valuable resource, although its full value is often hard to measure. Wildlife provides opportunities for study, general observation and hunting which in turn provide relaxation and enjoyment. These attributes are difficult to measure in any quantitative way.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

TABLE 1

HIGH DENSITY POPULATION AREAS

I. High Density Population Areas Identified in 1972/1973 by Colorado Division of Wildlife

Indicator Species	Distribution	Minimum Density (number of animals per square mile) For Classification as a High Density Population Area in the Denver Region
Big Game Species		
Mule Deer	Overall	.6
	Winter	1.3
White-tailed Deer	Winter	.4
Antelope	Winter	.8
	Distinct Biological Activity	All Areas
Elk	Winter	1.4
Bighorn Sheep	Overall	All Areas
	Winter	All Areas
	Distinct Biological Activity	All Areas
Black Bear	Overall	.1
	Winter	.1
Mountain Lion	Winter	All Areas
Small Game Species		
Blue Grouse	Overall	3.0
Pheasant	Overall	20.0
Turkey	Overall	All Areas
Wilson Snipe	Overall	All Areas

TABLE 1 (Cont.)

Indicator Species	Distribution	Minimum Density (number of animals per square mile) For Classification as a High Density Population Area in the Denver Region
Small Game Species		
Ptarmigan	Overall	All Areas
Band-tailed Pigeon		
Fox Squirrel	Overall	9.2
Snowshoe Hare	Overall	All Areas
Non-Game Species		
Prairie Falcon	Overall Distinct Biological Activity	All Areas All Areas
Peregrine Falcon	Overall	All Areas
Bald Eagle	Distinct Biological Activity	All Areas
Golden Eagle	Overall Distinct Biological Activity	.2 All Areas
Burrowing Owl	Overall	All Areas
Prairie Sharp-tailed Grouse	Distinct Biological Activity	All Areas
Abert's Squirrel	Overall	5.5
Bobcat	Overall	.3
Coyote	Winter Distinct Biological Activity	.7 All Areas
Badger		
Red Fox	Overall Distinct Biological Activity	.2 All Areas
Kit Fox	Distinct Biological Activity	All Areas
Gray Fox		

TABLE 1 (cont.)

Indicator Species	Distribution	Minimum Density (number of animals per square mile) For Classification as a High Density Population Area in the Denver Region
Non-Game Species		
Mink	Overall	1.7
Marmot	Overall	12.4
Coney (Pika)	Overall	All Areas
Prairie Dog	Overall	112.0

II. High Density Population Areas Identified in Winter 1977 by Colorado Division of Wildlife District Wildlife Conservation Officers

Species	Distribution	General Location of Habitat Area
Mule Deer	Winter	Ralston Reservoir South of Rocky Flats in Jefferson County.
	Overall and Winter	Eastward from Buckley Air National Guard Base in Arapahoe County.
Prairie Falcon	Overall	Leyden Gulch South of Rocky Flats in Jefferson County.
Wilson Snipe	Overall	Standley Lake in Westminster.
Goose		Marston Lake and Bowles Reservoir in southwest Denver.
Fox and Racoon		Bowles Reservoir and Bowles Lake area in southwest Denver.

TABLE 1 (Cont.)

III. High Density Population Habitat Areas for Prairie Dogs

In the fall of 1976 a special study on the locations of prairie dog towns was completed by the Colorado Division of Wildlife. The general locations of these prairie dog towns are listed by township and range in Appendix E.

IV. Wetland Habitat Areas Identified by the Boulder County Land Use Department

The Boulder County Land Use Department has identified wetlands in the plains area of Boulder County. These wetlands provide unique habitat for many species of birds and waterfowl. These habitat areas have been identified by numbers on habitat maps. Appendix F includes a listing of each habitat by number, general location and size.

TABLE 2

VERY HIGH DENSITY POPULATION AREA

I. Very High Density Population Areas Identified in 1972/1973 by Colorado Division of Wildlife

Species	Distribution	Minimum Density (number of animals per square mile) For Classification As A Very High Density Population Area in the Denver Region	Species Density (number of animals per square mile) In These Habitat Areas
Mule Deer	Winter	12.1	12.1
White-tailed Deer	Winter	.4	.4
			1.4
Elk	Winter	16.0	16.0
			20.3
			22.5
Bighorn Sheep	Overall	.7	.7
			2.6
	Winter	.7	.7
			2.4
	Historical Range	1.0	1.0
Blue Grouse	Overall	62.1	62.1
			74.8
Turkey	Overall	1.2	1.2
			1.5
			1.6
			2.1
			4.0
			6.4
			11.6
			14.2
Ptarmigan	Overall	11.9	11.9
			12.1
			12.8
			16.3

TABLE 2 (Cont.)

Species	Distribution	Minimum Density (number of animals per square mile) For Classification As A Very High Density Population Area in the Denver Region	Species Density (number of animals per square mile) In These Habitat Areas
Burrowing Owl	Overall	9.0	9.0 23.6 35.6
Marmot	Overall	12.4	12.4 16.2
Prairie Dog	Overall	355.5	355.5 375.3 401.7 413.2 445.9 773.4

II. Very High Density Population Areas Identified in Winter 1977 by Colorado Division of Wildlife District Wildlife Conservation Officers.

Species	Distribution	General Location of Habitat Area
Mule Deer	Winter	Areas between Highway 36 and the foothills in Boulder County from Lyons to the City of Boulder.
	Winter	Along hogbacks in Jefferson County from I-70 South to and including the area around Chatfield Lake.
White-tailed Deer	Overall	North of the City of Boulder
	Winter	Near Comanche Creek and Kiowa Creek in southern Adams County.
Antelope	Winter	Near Little Comanche Creek and West Bijou Creek in northern Arapahoe County.

TABLE 2 (Cont.)

Species	Distribution	General Location of Habitat Area
Antelope (Cont'd)	Critical Yearly Antelope Range	Near Kiowa Creek in northern Arapahoe County.
Elk		South of Lyons in central Boulder County.
	Winter	Northwest of Evergreen in Jefferson County.
	Winter	Between Conifer and Pine in western Jefferson County.
	Winter	Near Aspen Park in western Jefferson County.
	Winter	Near Turkey Creek in western Jefferson County.
Bighorn Sheep	Overall and Winter	South Platte Canyon in southern Jefferson County.
Prairie Falcon		Northwest of Rocky Flats in northern Jefferson County.
Abert's Squirrel	Overall	West of North Table Mountain in western Jefferson County.
Red Fox	Overall	Near Kountze Lake in Lakewood.
	Overall	Near Windsor Lake south of Lowry Air Force Base in east Denver.
	Overall	Along Highline Canal east of Aurora.
Varied Wildlife Deer (Mule & White tailed) Beaver Coyote Racoon Red Fox		South Platte River Valley between I-76 and the Union Pacific railroad north of Denver to around 104th Avenue

TABLE 2 (Cont.)

Species	Distribution	General Location of Habitat Area
Varied Wildlife Beaver Fisheries Waterfowl		Ponds & water filled gravel pits along Clear Creek in the far southwest corner of Adams County.
Varied Wildlife Mule Deer		Rocky Flats area in northern Jefferson County

III. Wildlife Habitats Identified by the Boulder County Land Use Department

Wildlife habitat areas have been identified by the Boulder County Wildlife Survey for the Boulder County Land Use Department. These areas provide unique habitat for a variety of species. The following is a list of these habitat areas, species which inhabit these areas and their general location.

Name	Species	General Location
Little Thompson River	Varied wildlife, great bird diversity	Along Boulder/Larimer County Line
St. Vrain Creek	Varied wildlife, great bird diversity	West of Longmont
Ish Reservoir	Varied wildlife	Far northeast corner of Boulder County
Terry Lake	Varied wildlife	North of Longmont
McCall Lake	Rare bird species	Between Lyons and Longmont
McIntosh Lake	Rare* bird species	Northwest of Longmont
Clover Basin Reservoir	Rare bird species, varied wildlife	Southwest of Longmont
Jim Hamm Nature Center	Rare bird species	East of Longmont

* In this table the term "rare" refers to birds which are either threatened or endangered nationwide or in Boulder County.

TABLE 2 (Cont.)

Name	Species	General Location
Haystack Mountain	Rare bird species, Striped Skunk, Prairie Dogs, Badger, and Racoon	North of Boulder Reservoir
Panama Reservoir	Rare bird species, waterfowl	North of Erie in the eastern part of Boulder County
Area directly east of Panama Reservoir	Great bird diversity	North of Erie
White Rocks area on Boulder Creek	Varied wildlife, native vegetation, rare ants, Mining bee, rare bird species	Along Boulder Creek northeast of Boulder
Heron Rookery on Boulder Creek	Great Blue Heron, waterfowl, varied birds	Along Boulder Creek west of Erie
Sawhill Ponds	Varied wildlife and birds, rare bird species	Northeast of Boulder
Waldon Ponds	Many species of birds and waterfowl, rare bird species	Northeast of Boulder
Cottonwood Grove on Boulder Creek	Varied wildlife and birds, rare bird species	North of Ball Brothers, northeast of Boulder
Valmont Reservoir	Rare bird species	East of Boulder
Teller Lake, Burke and Hartmann Lakes	Varied birds, Heron, Prairie Dogs, rare bird species	Between Boulder and Erie
Teller Lake #5	Rare bird species	Between Boulder and Erie
Prince Lake #1	Rare bird species	Between Erie and Lafayette
Marfel Lakes	Rare bird species	Between Erie and Lafayette
Baseline Reservoir	Rare bird species	Southeast of Boulder
Coal Creek	Fox, Striped Skunk, Racoon, Cottontail Rabbit, Pheasant, Hawk, Great Horned Owl, Great Blue Heron, Snakes, Lizards, Salamanders, rare bird species	Southeast of Louisville

IV. Wildlife Habitats Identified by the Adams County Planning Department

The Adams County Planning Department, with the technical assistance of the Colorado Division of Wildlife, has identified wildlife habitat areas which support very significant populations of varied wildlife species in Adams County. These areas, a listing of the major species which inhabit these areas,and the general location of the habitat are described below.

Name	Species	General Location
Barr Lake	Eagles, Cormorants, Heron, Waterfowl, Mule Deer, & White tailed Deer	Southeast of Brighton
Mile High Lakes	Significant Birdlife	East of Brighton
Horse Creek Reservoir	Varied Wildlife and Birdlife, Heron, Deer, Eagles, & Waterfowl	East of Brighton in northern Adams County
Rocky Mountain Arsenal	Varied Wildlife, Deer, Racoon, Opossum, Prairie Dog, Waterfowl, Raptors, & Songbirds	Western Adams County

TABLE 3

PRODUCTION HABITAT AREAS

I. Production Habitat Areas Identified in 1972/1973 by Colorado Division of Wildlife

Species	Species Density (# of Animals Per Square Mile) In These Habitat Areas
Mule Deer	15.2
Fawning Area	22.0
	274.1
Red Fox	
Denning Areas	2.4
	2.7
	2.8
	2.8
	3.0
	3.1
	3.3
	6.3
	7.6
Prairie Falcon	2.5
Nesting Area	
Golden Eagle	1.3
Nesting Area	1.4
Peregrine Falcon	.5
Special Overall Habitat For Endangered Species	

TABLE 3 (Cont.)

II. Production Habitat Areas Identified In Winter 1977 By Colorado Division of Wildlife District Wildlife Conservation Officers

Species	General Location of Habitat Area
Elk	West of Jamestown in Boulder County
	Between Conifer and Pine in western Jefferson County
Antelope	Near Little Comanche Creek and West Bijou Creek in northern Arapahoe County
Peregrine Falcon	Southern Jefferson County
Prairie Falcon	Near Ralston Buttes in western Jefferson County
Golden Eagle	Clear Creek Canyon in western Jefferson County
	Near Ralston Buttes in western Jefferson County
Red Fox	Near Kountze Lake in Lakewood
	Along Highline Canal east of Aurora
	Near Windsor Lake south of Lowry Air Force Base in East Denver

In economic terms, wildlife has amounted to greater than $130 million yearly enterprise in Colorado. Hunters and fishermen, as well as other wildlife enthusiasts, spend this amount of money each year on such things as sporting goods equipment, gas, food, lodging, etc. within the State. Recreation, which is Colorado's third largest industry, is largely dependent on wildlife, and recreation seems to be growing each year due to a greater amount of people, greater mobility, and greater amounts of leisure time.

Colorado's wildlife population has gone through many changes as a result of man's activities and their effect upon the environment. The Beaver was one of the first animals to feel man's effects in the West. The demand for Beaver hides for use in making Beaver hats almost wiped them out. The same fate happened to the Buffalo and Antelope that once dominated the wide open plains of Colorado. Only this time, the culprit was the extension of civilization in the form of fences, railroads, farms and cattle and sheep ranches. In the early 1900's, laws were passed protecting some of the game animals in the state and the Deer, Elk and Antelope populations began to rebuild and increase. However, some of these protective laws came too late to help some of the animals. The Wolf, River Otter, Black-Footed Ferret, Grizzly Bear, Wolverine, Trumpeter Swan and Whooping Crane are threatened with extinction, while the Buffalo are confined to small herds within fences. The Bighorn Sheep, which is Colorado's State animal, once lived on the plains, foothills and mountains, but now they can only be found in the mountainous areas. The Prairie Chicken and Sharp-Tailed Grouse are rarely seen and are on the list of endangered species for the State of Colorado.

In some instances, the species population has decreased by factors which have not affected the immediate species, but by factors which might have affected one of that species' predators. The interrelated predator/prey relationships have become unbalanced in many cases such that excess predation or lack of predation has occurred. Changes in temperature, moisture, light, food supply, and vegetative cover are all elements of a wildlife habitat, which when altered can adversely affect the ability of that species and its progeny to survive. Man's activities directly or indirectly effect these environmental elements which constitute wildlife habitat and consequently it is vitally important that those areas of significant wildlife habitat be recognized so that efforts can be made to protect these areas from such adverse effects.

A wildlife habitat is defined as a geographical area containing those elements of food, water, cover, space and general welfare in a combination and in quantities adequate to support a species for at least a portion of the year. A description of the five basic components of a good wildlife habitat is as follows:

(1) Food. Food must be of the right type and amount located where it can be obtained and eaten without danger to the animal.

(2) Water. Water must be available so that it can be used without danger to the animal.

(3) Cover. Cover is needed for production activities such as mating, nesting, and rearing young, and for winter protection and concealment from enemies and travel lanes.

(4) Space. Space is needed to prevent overcrowding. Each area has a certain carrying capacity and can support only a limited amount of animals.

(5) Arrangement. Arrangement is a combination of the other four components. Without proper arrangement the other essentials may be useless.

Wildlife habitat is also dependent on and affected by land ownership, topography, geography of the area, climate and many other variables. Wildlife habitat occurs in certain life zones or ecosystems of the environment. Appendix A includes a description of the major wildlife species and the dominant vegetation that is found in the varying ecosystems or life zones in Colorado.

There are several different types of threats to wildlife habitat in the DRCOG region. Much of the riparian habitat is threatened through development in the floodplains and structural flood protection devices. New housing developments in the mountains account for a substantial loss of habitat in the foothills and lower montane ecosystems or life zones and finally certain agricultural practices and cultivation practices account for the loss of habitat in the plains.

In order to determine what areas in the Denver region are significant wildlife habitat areas, it was necessary to obtain information on what species reside in the region and what is the significance of their occurrence in this area as compared to their significance and occurrence in other regions of the state. Data was first obtained from a statewide tabulation of "Wildlife Distribution by County and Species." This inventory was prepared in 1972 and 1973 by the Colorado Division of Wildlife based upon field counts of species made by the District Wildlife Conservation Officers throughout the State and was updated by supplemental data from 1974 hunting harvest reports.

The wildlife distribution tabulation showed the occurrence of 67 big game, small game and non-game species on a statewide basis. The occurrence of each species was also tabulated by three types of species occurrence: (1) an overall distribution of the species, (2) a winter distribution of the species, and (3) a distribution showing known

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areas of distinct biological activity for the species. Areas of distinct biological activity include such areas as migration routes, fawning, calving, nesting, breeding and other production areas, and historical range areas. In general, the areas for winter distribution are more constricted than for overall distribution, and the areas for distinct biological activity are more constricted than the range for both overall and winter distribution. The different sizes of the habitat areas for the different distributions (overall and winter) and activities tend to illustrate the varying specific needs of the species. The species habitat is a constriction based upon the specific needs of the species. Consequently, loss of habitat area means loss of a constricted unit fulfilling specific needs and demands of a certain species.

Of the 67 species tabulated on a statewide basis, it was found that 44 occur within the five-county Denver region and Douglas County. These 44 wildlife species, and their distribution by county for the Denver region, are shown in Table 4. Wildlife data for Douglas County has also been included in Table 4.

This list of 44 species which occur in the Denver region was then carefully evaluated with the assistance of the Wildlife Inventory Coordinator for the Colorado Division of Wildlife.[2] The purpose of this evaluation was to determine which of these species would be classified as indicator species for this region. Indicator species are those species which are found to be of particular significance to this region in terms of the importance of the presence of the species and the particular habitat it occupies. Particular weight was given to those species which are listed on either State or National lists of threatened or endangered species and to those species which have either known or suspected breeding or production sites within the region. The data for evaluation of breeding activity was obtained from the report, "Colorado Breeding Data for Select Bird Species."[3] Data indicating threatened and endangered species was obtained from National and State lists of endangered and threatened species for Colorado. A species is considered endangered when its prospects for survival and reproduction within an area are in jeopardy, or is likely to become so within the foreseeable future. It is basically a species that is in danger of extinction throughout all or a significant

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[2] Mr. Donald Schrupp is the Wildlife Inventory Coordinator for the Colorado Division of Wildlife.

[3] "Colorado Breeding Data for Select Bird Species" - Second Revision, May 1976, prepared by Walter D. Graul, Non-game Bird Specialist with the Colorado Division of Wildlife.

TABLE 4

WILDLIFE DISTRIBUTION WITHIN THE DENVER REGION

Species	Adams County	Arapahoe County	Boulder County	Denver County	Douglas County	Jefferson County
Mule Deer - Overall	X	X	X	X	X	X
Mule Deer - Winter	X	X	X	X	X	X
Mule Deer - Biological Activity	X				X	
White-tailed Deer - Overall	X		X		X	X
White-tailed Deer - Winter	X		X		X	X
Elk - Overall			X		X	X
Elk - Winter			X		X	X
Elk - Biological Activity					X	
Antelope - Overall	X	X			X	
Antelope - Winter	X	X			X	
Antelope - Biological Activity	X	X			X	
Bighorn Sheep - Overall			X		X	X
Bighorn Sheep - Winter			X		X	X
Bighorn Sheep - Biological Activity			X		X	X
Black Bear - Overall			X		X	X
Black Bear - Winter			X		X	X
Black Bear - Biological Activity					X	
Mountain Lion - Overall			X		X	X
Mountain Lion - Winter			X		X	X
Coyote - Overall	X	X	X	X	X	X
Coyote - Biological Activity	X	X	X			X
Prairie Dog - Overall	X	X	X		X	X
Burrowing Owl - Overall	X	X				
Peregrine Falcon** - Overall					X	X
Beaver - Overall	X		X		X	X
Kit Fox - Overall	X	X	X	X	X	
Kit Fox - Biological Activity	X	X				
Bobcat - Overall	X	X	X		X	X
Prairie Falcon - Overall	X	X	X	X	X	X
Prairie Falcon - Biological Activity	X				X	
Golden Eagle - Overall	X	X	X	X	X	X
Golden Eagle - Biological Activity	X		X		X	

* = on State list of endangered species.
** = on Federal and State list of endangered species.

Species	Adams County	Arapahoe County	Boulder County	Denver County	Douglas County	Jefferson County
Bald Eagle - Winter	X		X		X	X
Bald Eagle - Biological Activity					X	
Racoon - Overall	X	X	X	X	X	X
Jack Rabbit - Overall	X	X	X	X	X	X
Gray Fox - Overall	X	X		X	X	
Red Fox - Overall	X	X	X	X	X	X
Red Fox - Biological Activity		X	X			X
Badger - Overall	X	X	X	X	X	
Jumbo Frog - Overall			X			X
Striped Skunk - Overall	X	X	X	X	X	X
Marmot - Overall			X			X
Muskrat - Overall	X	X	X	X	X	X
Mink - Overall	X	X	X			X
Marten - Overall			X			
Cony - Overall			X			
Weasel - Overall	X	X	X	X	X	X
Turkey - Overall			X		X	X
Turkey - Biological Activity			X		X	X
Pheasant - Overall	X	X	X	X	X	X
Pheasant - Biological Activity	X	X		X		X
Snowshoe Hare - Overall			X			
Snipe - Overall and Winter	X				X	X
Prairie Sharp-tailed Grouse* - Overall					X	
Prairie Sharp-tailed Grouse - Biological Activity					X	
Abert's Squirrel - Overall			X		X	
Cottontail Rabbit - Overall	X	X	X		X	X
Cottontail Rabbit - Biological Activity	X	X				
Band-tailed Pigeon - Overall			X		X	X
Mourning Dove - Overall	X	X	X	X	X	X
Ptarmigan - Overall			X			
Blue Grouse - Overall			X		X	X
Fox Squirrel - Overall	X	X	X	X	X	X
Duck - Overall	X	X	X	X	X	X

* = on State list of endangered species.
** = on Federal and State list of endangered species.

Species	Adams County	Arapahoe County	Boulder County	Denver County	Douglas County	Jefferson County
Duck - Winter	X	X	X	X	X	X
Geese - Overall	X	X	X	X	X	X
Geese - Winter	X	X	X		X	X

Note : For purposes of this analysis, data from Douglas County is also included.

Source: Colorado Division of Wildlife, "Wildlife Distribution by County and Species," based on 1972 and 1973 Wildlife Inventory and 1974 Hunting Harvest Reports; plus additional information from Colorado Division of Wildlife staff.

portion of its range. Any substantial reduction or displacement of a wildlife population which results from a change in land use or man's activities could cause an otherwise stable population to become endangered. Endangered species are basically provided total protection by Federal law.

The State of Colorado has 14 endangered wildlife species. Three endangered species may be found in the Denver Region. These species are the Prairie Sharp-Tailed Grouse, the Peregrine Falcon, and the River Otter. The Peregrine Falcon is on both the State and Federal endangered species lists while the Prairie Sharp-Tailed Grouse and the River Otter are only on the State list. It is important to note that some Peregrine Falcon and River Otter have been raised in other regions of the nation and then transplanted to habitat areas in this region. It is hoped that these transplanted Falcon and Otter can form the basis for building up resident populations of these endangered species within this region. The specific bird and mammal species in the State of Colorado which are classified as endangered are listed in Appendix B.

A wildlife species is rated as threatened when the individuals constituting the species population exist in such small numbers or are so restricted in their general distribution that they may become endangered within the forseeable future throughout all or a significant portion of its range. Protection for threatened species varies considerably among the different species. Basically a threatened species is protected according to regulations set forth at the time the species is designated as "threatened." These regulations can vary from very little protection to almost absolute protection. In the State of Colorado, only two bird and mammal species are classified as threatened species. However, neither of these species inhabit the Denver Region. These species are also listed in Appendix B.

Based upon the above cited evaluation, 32 different species have been selected as significant indicator species for the Denver Region (Table 1, Part I). Three different groups of animals all have significant indicator species. These groups are big game animals, small game animals and non-game animals. The big game animals all have a habitat orientation to the mountains with the exception of the White-Tailed Deer and Antelope. Most of the small game animals are generally associated with the plains and the non-game animals are oftentimes species that support the big and small game species in some respect. It is important to remember that all three groups are interrelated and that many habitat areas include several species from several of these groups.

The next step in defining significant wildlife habitat was to evaluate mapped data of the locations of each of the indicator species in the

Denver Region. This data was once again available through the Colorado Division of Wildlife with the assistance of the Wildlife Inventory Coordinator. The data is in the format of map overlays at a scale of 1:500,000 which show the outline of known habitat areas. These habitat areas have been delineated by the District Wildlife Conservation Officers of the Colorado Division of Wildlife. The boundaries of these habitat areas represent the approximate limits of areas inhabited by an estimated population of the individual species. These boundaries were delineated based on field observation of where the species actually existed. This fieldwork and the species counts were taken in 1972 and 1973.

Data associated with each habitat area includes the area type (either overall distribution, winter distribution, or distribution of distinct biological activity), size of the area in square miles and acres, estimated population size within the area, and the animal density per square mile within the area. The most important data element is the animal density per square mile from which a determination could be made of what habitat areas supported a significant population of the species. These areal densities were ranked by species for their significance throughout the Denver Region and in comparison to rankings of high, medium and low areal densities on a statewide basis. The statewide average density is a figure based upon the average of the densities in areas where a particular species is known to exist. Areas that had high densities when compared to other densities in the region and against state average density figures were designated as high density population habitat areas.

In analyzing areas for designation as significant wildlife habitat, it became evident that certain habitat areas were of greater significance because these habitats were utilized for species production activity (i.e. nesting areas, fawning areas), and because certain of these habitat areas were relatively small in size but supported a very high density of a particular species. These special habitat areas have been designated as production habitat areas and as very high density population areas. In addition, a very small area of habitat for the Peregrine Falcon, an endangered species, is located in this region and those habitat areas have also been specially designated.

As indicated above, these habitat area definitions were set forth in 1972 and 1973. In an attempt to update this information, contact was made with each of the District Wildlife Conservation Officers in the region. From these meetings additional data was obtained on the present location, distribution and population size of various species within each of the wildlife conservation districts within the DRCOG region.[4] The habitat areas identified individually by District Wildlife Conservation Officers have been designated as significant wildlife habitat and may be classified as a "high density population area," a "very high density population area," or a "production habitat area."

Wildlife habitat areas have also been identified by some County Planning Departments within the region. These habitat areas generally support a very high density population of a large variety of species and consequently are generally classified as "very high density population areas" in this region. These areas, as well as those additional areas recently identified by CDW District Wildlife Conservation Officers are listed in Tables 1, 2 and 3.

Certain additional habitat areas which support significant populations of several different species were also identified by District Wildlife Conservation Officers of the Colorado Division of Wildlife. If the populations were quite large and the habitat localized to a relatively specific area, those areas were designated as very high density population habitat areas in the region. One of these identified habitat areas is located along Clear Creek east of Arvada. This small habitat area includes several ponds and provides good habitat for beaver, waterfowl and a diversified fishery. Another quality habitat area for varied wildlife is located along the South Platte River, north of I-270 up to approximately 104th Street. Species which inhabit the riparian areas along this river are Mule Deer, White-Tailed Deer, Red Fox, Coyote, Beaver, Racoon, Muskrat and Fox Squirrel.

Another important wildlife habitat is the Rocky Mountain Arsenal and the areas which surround it. It has been estimated that about 250 deer inhabit this area. Other small mammals inhabiting the Arsenal area include Opossum, Racoon, Weasel, Jackrabbit and Prairie Dog. In addition, its ponds and associated riparian vegetation make it good habitat for waterfowl, raptors and songbirds. The Rocky Flats site

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[4] The District Wildlife Conservation Officers contacted for updated habitat information in this region are as follows:

Tom Lynch - Adams County
Chuck Grand Pre - Adams County
Lee Rottman - Arapahoe County
Gary Brown - Boulder County
Russ Mason - Jefferson County
Mel DePra - Jefferson County
Ken Yoder - Jefferson County

in northern Jefferson County also is a special habitat for wildlife, most notably Mule Deer.

Certain areas in Adams County have been identified as important wildlife habitat areas by the Adams County Planning Department. Those areas were identified with the technical assistance of the Colorado Division of Wildlife. Included in these areas is the general area including and surrounding Barr Lake and Mile High Lakes which provides habitat for Cormorants and Eagles, which acts as a major waterfowl breeding and feeding area for shorebirds and migratory birds, and which includes a Heron rookery. In addition, more than 20 Mule Deer and more than 20 White-tailed Deer reside near Barr Lake. Another area identified as important wildlife habitat in Adams County is the area around Horse Creek Reservoir. This area supports Eagles, other birdlife, and Deer. The Rocky Mountain Arsenal was also identified as important wildlife habitat by the Adams County Planning Department because of the varied wildlife population that it supports. These habitat areas that were identified by the Adams County Planning Department with the technical assistance of the Colorado Division of Wildlife have been classified as very high density population areas for the DRCOG Regional Growth and Development Plan.

Other areas in Adams County also important for their functions of providing wildlife habitat are along the corridors of First Creek, Second Creek and Third Creek, and the South Platte River. These creek bottoms, as well as most of the creek bottoms in Adams County, support populations of Mule Deer, White-tailed Deer, Antelope, Red Fox and Coyote. The eastern portion of Adams County and Arapahoe County supports a sizeable Antelope population. In fact, it is estimated that there are three times more Antelope than Deer in the eastern portion of Adams County. Some Ferrets are also known to reside in the eastern portion of these two counties. The Plains Conservation Center which is located on the plains in Arapahoe County supports a variety of wildlife including such species as Deer, Antelope, Badger, Jack Rabbit, Cottontail Rabbit, Prairie Dog, and many rodents, owls, hawks and songbirds. The Plains Conservation Center has native short-grass prairie vegetation which is an important part of the wildlife habitat. The densities of individual species at the Plains Conservation Center, however, are of relatively equal significance to other areas of the plains in Arapahoe County.

Wetlands and wildlife habitat have also been identified in Boulder County by the Boulder County Land Use Department and include areas along the corridors of St. Vrain, Boulder and Coal Creeks, ponds and reservoirs such as Sawhill Ponds, Walden Ponds, Teller Lake, Panama Reservoir, Ish Reservoir, Terry Lake, Valmont Reservoir, and other areas. Included also are mountain habitat areas such as the areas surrounding Haystack Mountain. Wetlands were also identified in planning projects of the Boulder County Planning Department. Wetlands are important as wildlife habitat because they are areas for waterfowl breeding, wintering and migration stops. These wetlands have been designated as high density population areas and the other identified areas of wildlife habitat in Boulder County have been designated as very high density population areas. A listing of these wildlife habitat areas is included in Tables 1 and 2. Appendix F includes a specific listing of the location and size of the wetland habitats in Boulder County.

Special areas of existing wildlife habitat have not yet been identified by the Arapahoe County or Jefferson County Planning Departments, although the Jefferson County Planning Department has studied habitat suitability, migration and range areas and has identified areas of potential critical wildlife habitat. However, updated information (winter 1976/1977) on the location and distribution of many species in Jefferson and Arapahoe County was obtained from the Colorado Division of Wildlife District Wildlife Conservation Officers for Jefferson and Arapahoe Counties.

In addition to big game, small game and non-game mammals, many species of birds inhabit the DRCOG region. Songbirds, shorebirds and raptors all have some habitat within the region. Shorebirds in this region inhabit the riparian habitat of lakes, rivers, reservoirs and streams. Some shorebirds which do inhabit this region are Grebes, Cormorants, Herons, Bitterns, and Terns. This region is not on a great migration route, but both Greater Canada Geese and Lesser Canada Geese inhabit such areas as Barr Lake, Prospect Reservoir, Horse Creek Reservoir, Marston Lake, Bowles Reservoir, Standley Lake and gravel pits along Clear Creek in October and November each year. It is also important to note that there are Heron rookeries at Barr Lake, Chatfield Reservoir, and along Boulder Creek. These areas are also major waterfowl breeding and feeding areas. In addition, Sand Hill Crane inhabit Barr Lake, Prospect Reservoir, and Horsecreek Reservoir in October of each year. Other birds which inhabit and breed in this region include Swifts, Hummingbirds, Woodpeckers, Flycatchers, Wrens, Bluebirds, Warblers, Orioles, Grosbeaks, Sparrows, Hawks and Owls.

Many species of fish inhabit the streams, lakes, ponds and reservoirs of this region. Brook Trout and Brown Trout occur in water bodies in Boulder and Jefferson Counties, and Cutthroat Trout occur in western Boulder and Jefferson Counties. In addition, some small cold-water streams in the far western portions of the region even have Greenback Trout which is on the Federal list of endangered fish species. Rainbow

Trout are stocked in all the counties in the Denver Region and Crappie, Channel Catfish, Smallmouth Bass, Largemouth Bass, Yellow Perch, Blue Gill, Bullhead, Suckers, Carp, Freshwater Drum, and various Sunfish species all occur naturally and are stocked in all the counties in the region.

A description of the significant habitat areas for each of the indicator species in the region, the importance of that species to the region, and the density criteria for designation as significant wildlife habitat for that species are presented in Appendix C. Appendix D includes a list of all the indicator species, the statewide average density for those species, the range of densities in the Denver Region, and the required densities for specification as a high density population area, a very high density population area or a production habitat area.

Wildlife habitats are a very dynamic entity and can change quite rapidly over time with an alteration of any one of the elements of food, water, cover, space, and arrangement which comprise a wildlife habitat. It is basically an impossible task to identify all the habitats of endangered and threatened species or of species which we classed as indicator species for this region, completely and precisely to be valid over a long period of time.

The identification of wildlife habitat areas which were designated as environmentally sensitive areas in this region was based on the most up-to-date information that was presently available for this region. These habitat areas represent a picture of the presently known areal distribution of certain wildlife species within this region. Because locations of wildlife habitat areas can change rapidly, it is very important that serious consideration be given to the significance or consequences of development in a wildlife habitat, i.e. how that development might alter or eliminate one of the component elements of that habitat. In addition, it is very important that information on the locations of wildlife habitat be updated periodically.

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APPENDIX A

VEGETATION AND WILDLIFE OF ECOSYSTEMS OR LIFE ZONES IN COLORADO

(Animals specific to Denver Region)

Life Zone	Major Species	Dominant Vegetation
Alpine (Above Timberline) 11,500 ft.	Ptarmigan Red Fox Weasel Cony Marmot Bighorn Sheep Coyote Snowshoe Hare	Grass Sedges Alpine Flowers Mosses Lichens Dwarf Willows
Sub-Alpine 10,500 ft.	Elk Mule Deer (Summer) Bighorn Sheep Fox Snowshoe Hare Marten Weasel Beaver Coyote Bobcat Marmot	Small malformed Englemann Spruce and Sub-Alpine Fir Limber Pine
Montane 8,000 ft.	Mule Deer Elk Beaver Mink Marten Weasel Red Fox Gray Fox Black Bear Bobcat Skunk Mountain Lion Coyote Bighorn Sheep Snowshoe Hare Blue Grouse Bald Eagle Marmot Badger	Dense stands of: Englemann Spruce Firs Lodgepole Aspen Also: Limber Pines Douglas Fir Blue Spruce Mountain Ash Balsam Grassland parks

Life Zone	Major Species	Dominant Vegetation
Foothills 6,000 ft.	Mule Deer (Winter) Black Bear Striped Skunk Beaver Abert's Squirrel Muskrat Red Fox Gray Fox Bobcat Coyote Badger Turkey Doves Band-Tailed Pigeon Eagles Rabbits	Northern Desert Shrub (Biome) Douglas Fir Ponderosa or Yellow Pine Pinion Pine Juniper Blue Spruce Narrowleaf Cottonwood Wild Plum Chokecherry Serviceberry Mountain Mahogany Big Sage Rabbit Brush
Plains and Deserts 3,000 ft.	Antelope Cottontail Rabbit Jack Rabbit Kit Fox Red Fox Gray Fox Skunk Mule Deer White-Tailed Deer Beaver Muskrat Coyote Badger Prairie Dog Grouse Pheasant Golden Eagle Raccoon	Prairie Short-grass Yucca River Forests Broad-leaf Cottonwood Ash Elm Plum Box Elder Saltbrush Sycamore Hackberry Cactus Mesquite

Source: Exploring Wildlife, Unit 1; 1972 Colorado Division of Wildlife, Cooperative Extension Service, Colorado State University.

APPENDIX B

ENDANGERED AND THREATENED BIRD AND MAMMAL SPECIES IN THE STATE OF COLORADO

Endangered Species

Greater Prairie Chicken (S)
Prairie Sharp-tailed Grouse (S)
Mexican Duck (F)
American Peregrine Falcon (S) (F)
Arctic Peregrine Falcon (S) (F)
Whooping Crane (S) (F)
Greater Sandhill Crane (S)
Eskimo Curlew (F)
Gray Wolf (S) (F)
Grizzly Bear (S) (F)
Black Footed Ferret (S) (F)
Wolverine (S)
River Otter (S)
Lynx (S)

Threatened Species

White Pelican (S)
Lesser Prairie Chicken (S)

(F) On Federal lists of threatened and endangered species.

(S) On State lists of threatened and endangered species.

APPENDIX C

DESCRIPTIONS OF THE SIGNIFICANCE OF INDIVIDUAL INDICATOR SPECIES IN THE DENVER REGION

Big Game Species

MULE DEER

Mule Deer. Mule Deer have a natural habitat adaptability ranging from the plains, through the foothills (winter), through the montane ecosystems up into the sub-alpine life zones (summer). However, in the Denver region, the main concentrations are in the western parts of the region. They have basically been constricted to this area because of being pushed from the Denver valley by its urban development. The statewide average density for overall distribution is 2.9 animals per square mile. In Boulder County, there is an area whose density is 3.4 Deer per square mile for overall distribution which is above the state average, and which is the highest concentration area in the DRCOG region. However, areas with densities greater than .6 Deer per square mile for overall distribution are to be considered as significant for this region. These areas are in western Boulder and Jefferson Counties and in Douglas County. In addition, there is an area in the southeast corner of Arapahoe County that has a population density of 1.5 Deer per square mile which is an exceedingly high density for the plains area.

For winter distribution of Mule Deer, the statewide average density is 4.0 Deer per square mile which indicates that less area is suitable for winter habitat and that there is a general overall physical constriction into set habitat areas during that time. The winter habitat is more constricted to the foothills in this region and areas with densities greater than 1.3 are considered significant winter Mule Deer habitats for this region. Those areas with a density of 12.1 Deer per square mile are designated as very high density population areas. In addition, an area adjacent to the area specified as having a species density of 12.1 Deer per square mile in Boulder County has been designated as a very high density population area. This area of Mule Deer habitat was delineated by the Colorado Division of Wildlife, District Wildlife Conservation Officer for Boulder County.

In Jefferson County, there are also several areas of Mule Deer habitat, most notably along the hogbacks, that are also designated as very high density population areas. It is estimated that more than 300 Deer live along the hogbacks in the winter. There are three known distinct areas of biological activity (production and fawning) for Mule Deer in the region. They are located in Adams County and are specified as significant habitat and special production habitat areas due to their obvious importance as production areas. Population densities in these special areas range as high as 274 animals per square mile during production periods. Mule Deer are one of the more important species of the region in economic terms for hunting.

WHITE-TAILED DEER

White-Tailed Deer. White-Tailed Deer in Colorado are a plains oriented mammal and they are rarely seen in the mountains. They tend to congregate along river bottoms and, consequently, have a close tie to riparian habitat where greater cover is afforded. They are the source of the deer hunting season in the plains and are of some economic importance for this function. The statewide average density for winter distribution of White-Tailed Deer is .03 Deer per square mile. There are three habitat areas in the region which have been specified as significant habitat areas. One area is located in Adams County and has an animal density of 1.4 Deer per square mile, which is well above the state average. The second area is located in eastern Boulder County and has a density of .4 Deer per square mile which is also above the state average. The third area of White-Tailed Deer habitat is also located in Boulder County. This area was delineated by the Colorado Division of Wildlife (CDW), District Wildlife Conservation Officer for Boulder County and is for overall distribution of White-Tailed Deer. These areas are designated as very high density population areas because they have a high density population within a relatively small habitat area.

There are many more Mule Deer within this region than there are White-Tailed Deer. In fact, in Adams County it is estimated that there are five times more Mule Deer than White-Tailed Deer.

PRONGHORN ANTELOPE

Antelope. Antelope is a species which is unique to the plains. It is an important species for hunting and, presently, the hunting demand for Antelope exceeds the supply. Antelope habitat is being converted to irrigated farmland, lost to urban development, destroyed by highway construction and altered by private and federal management practices. The statewide average density of Antelope for winter distribution is .9 animals per square mile. Areas with densities ranging from .8 animals per square mile through 1.8 animals per square mile are located in Arapahoe and Douglas Counties and these areas are significant habitat areas for Antelope. The habitat boundaries for Antelope habitat were drawn in 1973 and since that time, the western edge of the habitat area may be pushed further east due to pressures from urbanization spreading further east.

An area of approximately nine square miles in eastern Douglas County has been important as a historical range for Antelope. Because of this importance, this area is also specified as significant wildlife habitat. There are also two habitat areas located in central Arapahoe County which are very critical production areas for Antelope. These areas were delineated by the CDW District Wildlife Conservation Officer for Arapahoe County and are consequently designated as important production habitat areas. In addition, it is important to note the land in the old Lowry Bombing Range supports a sizeable Antelope population. Other areas might also be of more significance for antelope given other agricultural practices on the land.

ELK

Elk. The Elk has a natural habitat area in the montane and sub-alpine life zones in the mountains. These areas are generally higher than 8,000 feet and on up to 11,500 feet in elevation. Vegetation in the montane life zone is usually composed of dense stands of Englemann spruce, firs, lodgepole pine, aspen, limber pines, Douglas fir, blue spruce, mountain ash, balsam and grassland parks. The sub-alpine life zone is generally vegetated with small malformed Englemann spruce and sub-alpine fir, and limber pines. Elk are the most economically important terrestrial species on a statewide basis. Elk are also an important indicator of change as they have a low tolerance for interference from human development of their habitat areas.

The DRCOG region has some very significant constricted winter habitat areas for Elk in western Boulder County. The statewide average density for winter distribution of Elk is 3.6 Elk per square mile. There are three areas in Boulder County where the densities range from 16 to 22 Elk per square mile. These three areas have been designated as very high density population areas. Another habitat area in Boulder County which has an estimated population of approximately 100 Elk has also been designated as a very high density population area. This area was delineated by the CDW District Wildlife Conservation Officer for Boulder County. In addition, a production habitat area for Elk is located in Boulder County. This area of Elk calving activity was also delineated by the CDW District Wildlife Conservation Officer for Boulder County and has been designated as an important production habitat area in this region.

In Jefferson County, many areas of important Elk habitat have been delineated by the CDW District Wildlife Conservation Officer for that area. These areas contain substantial sized herds of Elk for winter habitat and are located on the west edge of the county around Evergreen and Bergen Park, in a large area north of the North Fork of the South Platte River, and in the general area between Aspen Park and Fenders. In addition, an important Elk calving area is also located in Jefferson County, and these areas are delineated as very high density population areas and production habitat areas for this region. Other habitat areas with densities of 1.4 and above have been specified as high density population areas in the DRCOG region. A great deal of Douglas County is historical range for Elk which is also of importance.

BIGHORN SHEEP

Bighorn Sheep. The Bighorn Sheep is a species that fills two specific ecosystems. These are the sub-alpine and alpine ecosystems. The habitat area occupied by this species in the DRCOG region is very small. One area includes about 19 square miles and has an animal density of 2.5 per square mile. It is located in northern Boulder County. Another habitat area is located along the South Platte River between Douglas and Jefferson Counties. It is estimated that a resident herd of approximately 65 Sheep resides in this habitat area with the majority of the habitat area located on the Jefferson County side of the South Platte River. These areas have significant Bighorn Sheep population densities for both overall and winter distribution. Information showing the historical range area for this species in the region shows that its habitat area has been severely reduced. The Bighorn Sheep is generally intolerant of any permanent human encroachment, and it will constrict its habitat area to avoid any such interference. However, a Bighorn Sheep was sited in the developed area of Boulder Canyon in 1976. The presence of Bighorn Sheep in the DRCOG region should be especially important since the Bighorn Sheep is the State animal. All Bighorn Sheep known habitat areas in this region have been designated as very high density population areas.

BLACK BEAR

Black Bear. The Black Bear is generally associated with the montane life zone. In the DRCOG region, the Black Bear can be found in Boulder County and the far northwestern corner of Jefferson County. In fact, it is interesting to note that a Black Bear even rambled into the City of Boulder and Eldorado Springs in the fall of 1976. Four Black Bear were sited at different times in 1976 around Conifer and Aspen Park and three Black Bear found it enjoyable to visit Tiny Town in 1976.

The statewide average Black Bear densities for overall and winter distribution is .1 Bear per square mile. Those areas in Boulder County with a Black Bear density of .1 and greater are considered to be high density population areas for Black Bear in this region. The Black Bear is of economic importance for hunting in this region. However, a significant number of Black Bear are being killed by unlicensed individuals who are permitted to take bear in areas grazed by livestock.

MOUNTAIN LION

Mountain Lion. The Mountain Lion's distribution is generally very thinly spread over a wide area which is characteristic of its large home range. Some Mountain Lion do inhabit areas in the western portions of Boulder and Jefferson Counties, as well as in southeastern Douglas County. It is estimated that only four or five mountain lions inhabit Boulder County. Mountain Lion have also been spotted around Morrison, Mount Morrison, Ralston Buttes and Waterton Canyon in Jefferson County. The Mountain Lion is generally associated with the montane life zone. The statewide average density for winter distribution is .01 Mountain Lion per square mile or one Mountain Lion per 100 square miles. Because the occurrence of Mountain Lions is quite limited, any potential or known habitat area is of significance and will be specified as significant wildlife habitat high density population areas for the purposes of this study.

Small Game Species

SHARP-TAILED GROUSE

Prairie Sharp-tailed Grouse. The Prairie Sharp-tailed Grouse is a significant species for this area because it is on the State of Colorado endangered species list. Because of the endangered status, it is closed to hunting in this region. The habitat of the Prairie Sharp-tailed Grouse is mid to tall grass prairie interspersed with tall shrubs such as oakbrush. An area of historical range does exist in Douglas County, and the species still exists there. There has been evidence of Prairie Sharp-tailed Grouse breeding (nesting) within the region within the last ten years. This species, however, does not occur within the five-county Denver Region.

BLUE GROUSE

Blue Grouse. Blue Grouse has a habitat of the montane life zone or ecosystem type. When compared to other eastern slope Blue Grouse habitat areas, there are relatively high concentrations of Blue Grouse in Boulder County, although they are also found in the southern and western portions of the DRCOG region. The statewide average density of Blue Grouse for an overall distribution is 2.8 Grouse per square mile. Those areas in the DRCOG region with a density greater than this figure have been classified as high density population areas for Blue Grouse. Certain of the Blue Grouse habitat areas support a very high population of Grouse in relatively small habitat areas. Those areas with a species density greater than 62 Blue Grouse per square mile have been designated as very high density population areas.

All of the Blue Grouse significant habitat areas are located in western Boulder County. The Blue Grouse is a very trusting bird and is, consequently, very susceptible to killing by hunters provided they can be located within the great expanse of their habitat.

Pheasant. Pheasants inhabit the plains ecosystem. They are an important small game species for hunting and are affected by much of the agricultural practices on the plains. The historical range for Pheasants was much closer to Denver, however, they have now moved out further into the plains. The statewide average distribution shows densities greater than 14.8 Pheasant per square mile as high densities. Consequently, those areas with densities of 20 and 30 Pheasants per square mile are high density population areas for this region and the State as a whole.

PHEASANT

Turkey. The mere fact that wild Turkey exist in the DRCOG region makes their habitat significant. All the Turkey population in this region are constricted into small habitat areas. A comparison of the existing habitat with the species historical range shows drastically how the species has been constricted to small areas of higher concentrations instead of the large historical range that once covered most of southern and western Jefferson and Douglas Counties. The Turkey is generally found in the foothills ecosystem. The average statewide density for overall distribution of Turkeys is 1.1 per square mile. All areas in the region (densities 1.2 through 14.2 Turkeys per square mile) are included in the specification of very high density population areas.

WILD TURKEY

Wilson Snipe. Wilson Snipe is a shorebird which has a small and localized occurrence that is usually tied with a riparian habitat. In the DRCOG region, there are several small areas where a sizeable Snipe population is currently known to exist. These are in western Adams County, northern Jefferson County, around Barr Lake, around Standley Lake and in certain areas along the South Platte River east of Thornton. The average statewide distribution of Snipe is 4.8 per square mile. In the DRCOG region, all habitat areas will be specified as high density population areas. The densities in these areas range from 2.9 through 6.7 Snipe per square mile.

Ptarmigan. The Ptarmigan is a member of the Grouse family that occupies the alpine and sub-alpine ecosystems. The alpine ecosystem (area above the timberline) has a small amount of vegetation and that which does exist is very small in size. Common vegetation in the alpine ecosystem are grasses, sedges, alpine flowers, mosses, lichens and dwarf willows. The

WHITE-TAILED PTARMIGAN

average statewide density for overall distribution of Ptarmigan is 8.3 per square mile. In the far western alpine areas of Boulder County, there are several areas whose densities range from an estimated 12 to 16 Ptarmigan per square mile which is well above the State average. These high density population areas are designated as very high density population areas in the region. In general, the Ptarmigan's habitat is naturally protected because of its high elevation. All habitat areas of the Ptarmigan in this region will be specified as significant wildlife habitat areas.

BAND-TAILED PIGEON

Band-Tailed Pigeon. The Band-Tailed Pigeon has an association with pinion-juniper areas in the montane life zone, however, they do occur in other areas of the DRCOG region. They generally have a seasonal occurrence in the fall of the year as they come through this region during migration. Those densities considered to rank high on a statewide basis are those greater than 33.1 Pigeons per square mile. In the DRCOG region, the overall densities are .8 and 1.5 per square mile which is not important on a statewide basis. However, it is important to note that this species does exist in this area.

Abert's Squirrel. The Abert's Squirrel has a specific habitat association with the forest types of Ponderosa Pine and Douglas Fir found in the foothills life zone. The statewide average density for overall distribution of Abert's Squirrel is 4.7 per square mile. In the DRCOG region, those areas which have a density of 5.5 or greater have been designated as high density population areas for Abert's Squirrel. These areas are all located in the foothills in Boulder County except for one small habitat area in western Jefferson County. In addition, an area in Jefferson County where there are very high concentrations of Abert's Squirrel was delineated by staff of the Colorado Division of Wildlife and that area is designated as a very high density population area.

FOX SQUIRREL

Fox Squirrel. The Fox Squirrel is one species that does well in association with people. Its distribution is peculiar to the plains drainage systems. The habitat area for this species is in the Platte Valley and it does not live far into the mountains or on the plains. In this region Fox Squirrels habitat is found along creeks and in the large old trees in developed areas. The statewide average density for overall distribution of Fox Squirrel is 8.7 per square mile. In the DRCOG region, certain habitat areas exist where the Fox Squirrel density is projected at over 200 animals per square mile. This figure is exponentially greater than the statewide average. All habitat areas with densities greater than the statewide average will be specified as high density population areas for this region.

SNOWSHOE HARE

Snowshoe Hare. The Snowshoe Hare inhabits those ecosystem types from the coniferous forests of the montane life zone to the timberline. They are of economic value, as are other small game species, for hunting. In the DRCOG region, the Snowshoe Hare are found only in western Boulder County. The average statewide density for overall distribution of Snowshoe Hare is 6.7 Hare per square mile. In Boulder County, there are two Snowshoe Hare habitat areas with densities of 11.2 and 2.9 Hare per square mile. Both of these areas are designated as high density population areas.

Non-Game Species

Prairie Falcon. The Prairie Falcon is a raptor and as such is protected by Federal law. Raptors cannot be held in captivity without a proper license (for falconry) and it is illegal to shoot any raptor. All raptors are significant in terms of aesthetics and in terms of their function of rodent control. The statewide average density for overall occurrence of Prairie Falcon is .3 per square mile. Their mere occurrence in this region is significant. A gross estimate of statewide Prairie Falcon population in 1973 showed 150 known pairs of Prairie Falcons. A known nesting area exists slightly northeast of Denver in Adams County. This area is of particular significance and has a density of 2.5 Falcons per square mile. Another Prairie Falcon nesting area is located around Ralston Buttes in Jefferson County. All raptors have an association with riparian habitat for nesting purposes, however, for general distribution their habitat is on cliffs in basically all habitat types. All Prairie Falcon habitat areas are to be specified as high density population areas and the nesting areas are specified as important production habitat areas.

Peregrine Falcon. The Peregrine Falcon has been listed on both the State and Federal lists of endangered species. Therefore, any area which provides a habitat for these species or any area where they are known to exist is significant. It is estimated that three small habitat areas for Peregrine Falcon exist in this region. All of these areas are designated as especially important significant wildlife habitat. In addition, nesting activity for Peregrine Falcon exists in one known site in the region and that area is designated as important production habitat.

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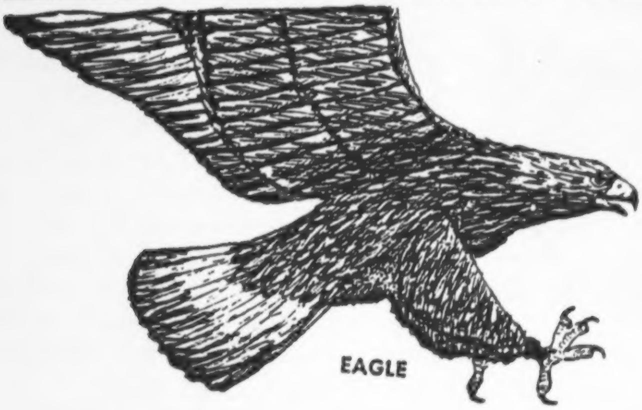
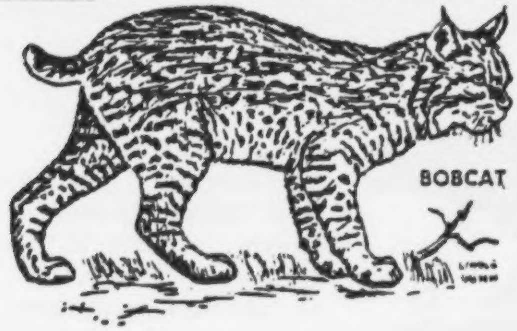
Bald Eagle. The Bald Eagle is of special significance since it is the national bird. Its habitat is usually riparian cottonwood or coniferous forests near lakes or large rivers. In 1973, it was estimated that 400 Bald Eagles wintered within the State of Colorado. However, at that time, only one Eagle was estimated to live in this region. That one site is in the southern portion of Douglas County and it is consequently specified as a significant habitat area. Potential winter habitat for Bald Eagle within the region is near Barr Lake Reservoir or Horse Creek Reservoir in Adams County.



Golden Eagle. The Golden Eagle, along with the three previously listed species is also a raptor and, as such, is afforded special protection. Golden Eagles are relatively widespread throughout the State and in 1973 it was estimated that approximately 4,000 Golden Eagles wintered within the State. They have habitat in all ecosystems except the alpine ecosystem which is higher in elevation than the timberline.

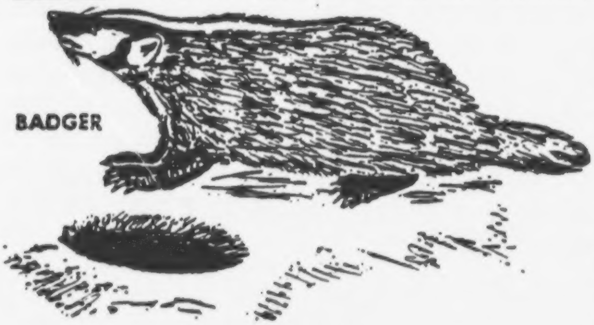
The statewide average density for the overall distribution of Golden Eagles is .03 per square mile and those areas with densities greater than .2 Eagles per square mile are considered high on a statewide basis. Therefore, all habitat areas with density greater than .2 Eagles per square mile in the DRCOG region are designated as high density population areas. In addition, there are four areas of breeding or nesting in the region. Because of the biological importance of these areas, they are specified as significant production habitat areas for the Golden Eagle.

Burrowing Owl. The Burrowing Owl is a raptor who is a ground nester on a plains habitat of shortgrass or semi-arid grasslands. In 1973 it was found in three very small habitat areas on the plains in Adams and Arapahoe Counties. However, its population size and distribution have both been increasing since that time. The statewide average density for overall distribution is .1 Owl per square mile. The densities in these three habitat areas range from 9 to 35.6 Owls per square mile which is many times greater than the state average density. Therefore, all the habitat areas for Burrowing Owl within this region are designated as high density population areas. In addition, there has been definite evidence of breeding in this region in the past ten years which lends more importance to these areas.



Bobcat. The Bobcat occupies a habitat ranging from the foothills through the sub-alpine ecosystem. The density of the species increases as the distance from the metropolitan area increases, thus suggesting the species intolerance to encroachment. The average statewide density for overall distribution of Bobcat is .3 per square mile. All habitat areas which have a density greater than the statewide average are specified as high density population areas. These habitat areas occur in southern Jefferson County, southeastern Douglas County and northern Boulder County. Some concern exists over the future size of the Bobcat population because of pressure to trap the Bobcat for their hide. Within the past year Bobcat hides were worth up to $300 per hide.

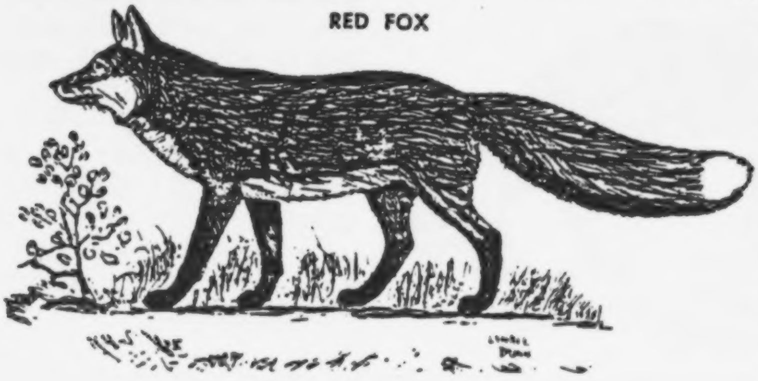
Coyote. The Coyote occupies habitats ranging from the plains along the hogbacks, and up through the sub-alpine ecosystem. It is a species that is well distributed throughout the State and which is important for rodent control. The statewide average estimated density for winter distribution of Coyote is .7 per square mile. All habitat areas within the DRCOG region with densities greater than .7 Coyote per square mile will be designated as high density population areas. There are three such areas within the region and all are rather small. In addition, there are several concentration areas of distinct biological activity, most logically, denning. Because of the importance of these areas in terms of concentration and possible production, these areas are also specified as significant production habitat areas.



Badger. The Badger occurs in the montane through plains ecosystems, although in the DRCOG region they are mainly found in the plains habitat. The statewide average density for overall distribution of Badger is .2 per square mile. In the DRCOG region, the habitat areas for Badger include a good deal of Adams and Arapahoe Counties and the southeastern corner of

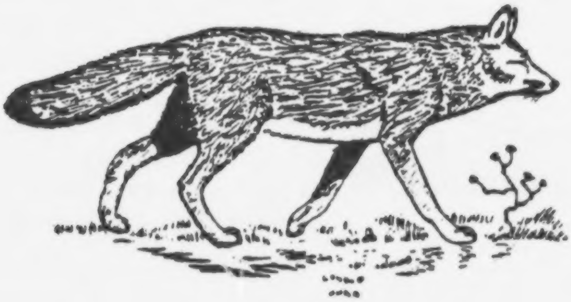
Boulder County. The species densities for Badger in these areas are about .4 per square mile. Since the habitat area for Badger covers most of the plains, it is impractical to designate these areas as significant habitat areas. However, it is important to note that the Badger does exist in this region.

Red Fox. The Red Fox is one species which can occupy habitat ranging from the plains to the alpine ecosystem, although it is more commonly found on the plains especially along dry creek beds. Sometimes, however, they do occur in mountain meadows and they also inhabit the hogback areas and creek bottoms in mountain and foothill areas. The Red Fox is important for its function of rodent control and for aesthetics. The statewide average density for overall distribution of the Red Fox is .2 per square mile. All those habitat areas in the DRCOG region with densities higher than the statewide average have been specified as high density population areas. In addition, there are several areas of distinct biological activity which are denning site locations. Because of the important biological nature of these areas, they are specified as important species production habitat areas. The densities in these production areas range from 2.4 - 7.6 Fox per square mile. Red Fox denning areas on the eastern side of Jefferson County and in Arapahoe County have been identified by the Colorado Division of Wildlife District Wildlife Conservation Officers for those areas. No density figures are available for these areas, but they are still designated as important production habitat areas.


RED FOX

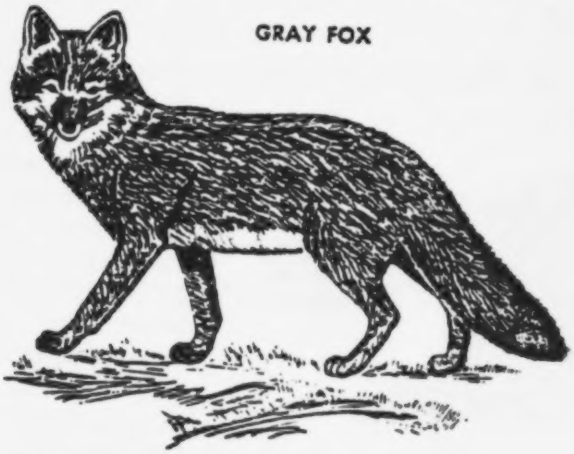
Kit Fox. The Kit Fox inhabits the plains ecosystem. It is a species that is trapped (along with the other Fox species) and is of some economic significance. The large habitat area for Kit Fox in the DRCOG region covers most of the plains of Adams and Arapahoe Counties. It is estimated that a population of about 600 Kit Fox occupy this area for an average density of .4 Fox per square mile. Since most

KIT FOX

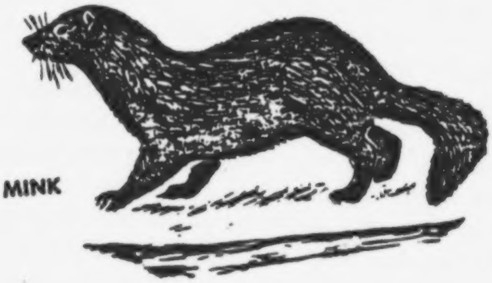


of the plains are included as Kit Fox habitat area, it would be impractical to designate it all as significant habitat. However, it is important to note that the Kit Fox does exist in this area.

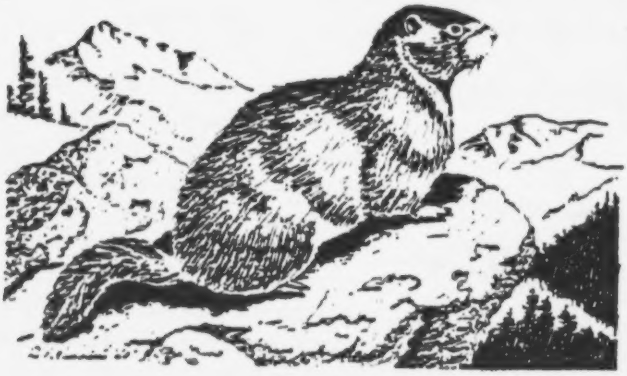
Gray Fox. The Gray Fox occurs mainly in plains counties although it can occupy areas up through the montane ecosystem. The statewide average density for overall distribution is .4 Gray Fox per square mile. The densities in this region are lower than the state average, however, the occurrence of Gray Fox in this region is noteworthy. Gray Fox is trapped, as well as other Fox species and is of economic importance for this activity.


GRAY FOX

Mink. The Mink is a species associated with riparian habitat. Its demand for use in fur coats has diminished in recent years; however, it is still trapped. The statewide density for overall distribution of Mink is .7 per square mile. Areas in the DRCOG region with densities of 1.7 through 9.4 Mink per square mile have been designated as high density population areas for Mink.


MINK

Marmot. The Marmot is a species which lives in the montane through alpine ecosystems. The Marmot is a significant species because it is unique to the alpine ecosystem and the major population concentrations are in the alpine ecosystems in this region. The statewide average density for overall distribution of Marmot is 3.8 per square mile. Those areas in this region with densities greater than the statewide


MARMOT

average are designated as high density population areas. Those habitat areas with species densities of 12.4 or greater are designated as very high density population areas.

Coney. The Coney (or Pika) inhabits the alpine and sub-alpine ecosystems and is consequently found only in the far western portions of Boulder County in this region. It is unique to high elevation ecosystems. The Coney is a food base for raptors and where they do exist, they generally occur in goodly numbers. The state average density for overall distribution of Coney is 32.6 per square mile. In this region, all habitat areas of the Coney have a density greater than the State average and are therefore all designated as high density population areas.

PRAIRIE DOG

Prairie Dog. The Prairie Dog's habitat is in small, localized, identifiable communities usually on the plains, but sometimes extending up into the mountains. Prairie Dog habitat on the plains occurs in areas which have not been cultivated for agricultural uses. The Prairie Dog is of particular importance because it has a known interrelationship with the Black-Footed Ferret which is on the Federal list of endangered species. It is also a food source for raptors. The statewide average density for overall distribution of Prairie Dogs is 4.1 per square mile. The statewide ranking indicates all densities over 104.6 Prairie Dog per square mile to be high on a statewide basis. Therefore, all Prairie Dog habitats which have a density greater than 104.6 are designated as high density population areas. In addition, certain known habitat of Prairie Dogs was mapped in the fall of 1976. These Prairie Dog habitat areas have also been designated as high density population areas even though no data on the population densities of the species is available for these habitat areas. Those areas that have densities greater than 355 Prairie Dog per square mile have been designated as very high density population areas because of the large number of Prairie Dogs which are inhabiting quite small habitat areas.

APPENDIX D

INDICATOR SPECIES DENSITIES

(Number of Animals Per Square Mile in Estimated Habitat Areas)

Species	Statewide Average Density	Range of Densities in Denver Region	Classified as High Density Population Area for Denver Region (Densities ≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities ≥)
BIG GAME				
Mule Deer				
O	2.9	.1 - 3.4	.6	
W	4.0	.03 - 12.1	1.3	12.1
DBA (production area - fawning)		15.2 - 274.1	All Areas	All Areas
White-tailed Deer				
W	.03	.004 - 1.4	.4	.4
Antelope				
W	.9	.2 - 1.8	.8	
DBA (historical range)		3.2	All Areas	

Species	Statewide Average Density	Range of Densities in Denver Region	Classified as High Density Population Area for Denver Region (Densities ≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities ≥)
Elk				
W	3.6	.2 - 22.5	1.4	16.0
Bighorn Sheep				
O	.8	.7 - 2.6	All Areas	All Areas
W	1.5	.7 - 2.4	All Areas	All Areas
DBA (historical range)		1.0 - 1.9	All Areas	All Areas
Black Bear				
O	.1	.02 - .7	.1	
W	.1	.02 - .7	.1	
Mountain Lion				
W	.01	.008 - .02	All Areas	
SMALL GAME				
Blue Grouse				
O	2.8	.1 - 74.8	3.0	62.1

Species	Statewide Average Density	Range of Densities in Denver Region	Classified as High Density Population Area for Denver Region (Densities≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities≧)
Pheasant				
O		10.0 - 30.0	20.0	
Turkey				
O	1.1	1.2 - 14.2	All Areas	1.2
Wilson Snipe				
O	4.8	2.9 - 6.7	All Areas	
Ptarmigan				
O	8.3	3.9 - 16.3	All Areas	11.9
Band-tailed Pigeon				
O		.8 - 1.5		
Fox Squirrel				
O	8.7	1.5 - 238.4	9.2	
Snowshoe Hare				
O	6.7	2.9 - 11.2	All Areas	

Species	Statewide Average Density	Range of Densities In Denver Region	Classified as High Density Population Area for Denver Region (Densities ≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities ≥)
NON-GAME				
Prairie Falcon				
O	.3	.1 - .8	All Areas	
DBA (nesting)		2.5	All Areas	All Areas
Peregrine Falcon				
O	.3	.5	All Areas	All Areas
Bald Eagle				
DBA		1.2 (In Douglas Co.)	All Areas	
Golden Eagle				
O	.03	.003 - 1.5	.2	
DBA		1.3 - 1.4	All Areas	All Areas
Burrowing Owl				
O	.1	9.0 - 35.6	All Areas	All Areas

Species	Statewide Average Density	Range of Densities in Denver Region	Classified as High Density Population Area for Denver Region (Densities≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities≥)
Prairie Sharp-tailed Grouse				
DBA (historical range)			All Areas	
Abert's Squirrel				
O	4.7	.4 - 13.6	5.5	
Bobcat				
O	.3	.04 - .5	.3	
	.3			
Coyote				
W	.7	.1 - 1.2	.7	
DBA (concentration area - possible denning)		.9 - 4.4	All Areas	
Badger				
O	.2	.1 - .5		

Species	Statewide Average Density	Range of Densities in Denver Region	Classified as High Density Population Area for Denver Region (Densities ≥)	Classified as Very High Density Pop. Areas or as Production Habitat Area (Densities ≥)
Red Fox				
O	.2	.1 - 1.9	.2	
DBA (denning)	2.1	2.4 - 7.6	All Areas	All Areas
Kit Fox				
O	.1	.1 - .4		
Gray Fox				
O	.4	.21 - .25		
Mink				
O	.7	.1 - 9.4	1.7	
Marmot				
O	3.8	1.5 - 16.2	12.4	12.4
Cony				
O	32.6	34.6 - 109.9	All Areas	
Prairie Dog				
O	4.1	20.2 - 773.4	112.0	355.5

O = Overall Distribution
W = Winter Distribution
DBA = Distinct Biological Activity

APPENDIX E

Location of Prairie Dog Towns
Identified in Fall 1976
by Colorado Division of Wildlife
(Township, Range, Section)

T3N, R70W, Sections 8, 10, 11, 15, 16, 33, 34
T3N, R69W, Section 1
T2N, R70W, Sections 3, 4, 7, 8, 9, 10, 16, 17, 18, 23, 24, 25, 26, 27, 32, 34, 35
T1N, R71W, Sections 13, 19, 20, 24
T1N, R70W, Sections 2, 3, 5, 6, 10, 16, 23, 24
T1N, R69W, Sections 15, 16, 18, 19, 30
T1S, R70W, Section 2
T1S, R68W, Sections 1, 10, 11, 12, 13, 14, 15, 22, 23, 24, 26, 27, 28, 30, 33
T1S, R67W, Sections 1, 2, 32, 36
T1S, R66W, Sections 22, 23
T1S, R65W, Sections 1, 3, 4, 5, 8, 9, 10, 31
T1S, R64W, Sections 5, 6, 8, 17
T1S, R63W, Sections 3, 4, 9, 10
T2S, R68W, Section 1
T2S, R67W, Sections 6, 7, 12, 18, 25, 26, 33, 35, 36
T2S, R66W, Sections 11, 12, 16, 17, 19, 29, 30, 32
T2S, R65W, Section 19
T3S, R67W, Section 11
T3S, R64W, Sections 9, 15, 16, 21, 22
T3S, R63W, Sections 11, 14
T4S, R66W, Sections 5, 7, 8, 20, 23, 24, 25, 26
T4S, R65W, Section 31
T4S, R64W, Sections 6, 7, 8
T4S, R63W, Sections 23, 26
T5S, R66W, Sections 3, 7, 20, 27, 28
T5S, R65W, Sections 1, 12, 29
T5S, R64W, Sections 4, 5, 6, 7

APPENDIX F

WETLANDS OF BOULDER COUNTY

Identifying Number On Habitat Map	General Location	Approximate Size
1	Baseline Road NW 1/4, Sec. 1, T1S, R69W & SE 1/4, Sec. 36, T1N, R69W	5-10 Acres
2	County Line Road SE 1/4, Sec. 36, T2N, R69W	5 Acres
4	Hygiene Road SE 1/4 Sec. 25, T3N, R70W	5-10 Acres
5	County Line Road SE 1/4 Sec. 24, T3N, R69W	5 Acres
6	County Line Road NE 1/4 Sec. 1, T3N, R69W	5-10 Acres
8	County Road 3 SE 1/4 Sec. 2, T3N, R69W	5-10 Acres
9	County Road 31 NE 1/4 Sec. 13, T3N, R70W	5-10 Acres
10	Foothills Highway NE 1/4 Sec. 29, T3N, R70W	5 Acres
11	Nelson Road SW 1/4 Sec. 11, T2N, R70W	5 Acres
12	N. 65th Street NW 1/4 Sec. 11, T2N, R70W	5 Acres
13	County Road 41 S 1/2 Sec. 34, T3N, R70W	10-15 Acres
14	County Road 51 NW 1/4, Sec. 4, T2N, R70W	5 Acres
15	County Road 33 NW 1/4, Sec. 24, T2N, R70W	5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
16	63rd Street, County Road 39 NE 1/4 Sec. 15, T2N, R70W	5 Acres
17	County Road 39 NE 1/4 Sec. 15 & NW 1/4 Sec. 14, T2N, R70W	5 Acres
18	Neva Road SE 1/4 Sec. 30, T2N, R70W	5 Acres
19	Hover Road SW 1/4 Sec. 28, T2N, R69W	5 Acres
20	Kenosha Road NE 1/4, Sec. 12, T1N, R69W	5-10 Acres
21	County Road 10 SE 1/4 Sec. 25, T3N, R69W	10-15 Acres
22	N 95th Street NE 1/4 Sec. 17, T1N, R69W	5 Acres
23	Colorado 287 SE 1/4, Sec. 10, T1N, R69W	10-15 Acres
24	Colorado 287 NW 1/4, Sec. 34, T1N, R69W	5 Acres (Has been drained)
25	N 109th St., County Road 9 SE 1/4, Sec. 15, T1N, R69W	5 Acres
26	N 109th St., County Road 9 NE 1/4, Sec. 10, T1N, R69W	5 Acres
27	Eldorado Springs Drive NE 1/4, Sec. 30, T1S, R70W	5-10 Acres
28	Marshall Drive N 1/2, Sec. 22, T1S, R70W	5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
29	Empire Road, County Road 42 NE 1/4, Sec. 16, T1S, R69W	5-10 Acres
30	Colorado 287 SE 1/4, Sec. 15, T1S, R69W	5 Acres
31	S 104th St., County Road 13 SW 1/4, Sec. 22, T1S, R69W	5 Acres
32	Brainard Drive, County Road 19 SE 1/4, Sec. 28, T1S, R69W	10-15 Acres
33	Delaney Road, County Road 64 SW 1/4, Sec. 28, T1S, R69W	5 Acres
34	County Road 52 SE 1/4, Sec. 20, T1N, R69W	5-10 Acres
35	N 51st St., County Road 51 SW 1/4, Sec. 4, T1N, R70W	10-15 Acres
36	NW 1/4 Sec. 7, T3N, R69W	5 Acres
37	N 83rd St., County Road 23 South of Knoth Reservoir SW 1/4, Sec. 7, T3N, R69W	5 Acres
38	North of Highland Reservoir #2 NW 1/4, Sec. 5, T3N, R69W	5-10 Acres
39	N 89th St., County Road 23 SW 1/4, Sec. 17, T3N, R69W	5 Acres
40	North of Walker Reservoir NW 1/4, Sec. 14, T3N, R69W	5 Acres
41	Near Highland Ditch SW 1/4, Sec. 13, T3N, R69W	5-15 Acres
42	Near Highland & Rough and Ready Ditches NE 1/4, Sec. 21, T3N, R70W	5 Acres 5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
43	Between Highland and Rough and Ready Ditches NW 1/4, Sec. 22, T3N, R70W	5 Acres
44	Ute Road NW of McCall Lake SE 1/4, Sec. 22, T3N, R70W	5 Acres
45	Ute Road NE of McCall Lake SE 1/4, Sec. 23, T3N, R70W	5 Acres
46	Ute Road North of McIntosh Lake SE 1/4, Sec. 19, T3N, R69W	5 Acres
47	Ute Road NE of McIntosh Lake NW 1/4, Sec. 30, T3N, R69W	5 Acres
48	Vermillion Road SE 1/4, Sec. 13, T3N, R69W	5 Acres
49	Vermillion Road NE 1/4, Sec. 24, T3N, R69W	5-10 Acres
50	Ute Road NE of McIntosh Lake NE 1/4, Sec. 29, T3N, R69W	5 Acres
51	N 95th St., County Road 19 SE 1/4, Sec. 28, T3N, R69W	5 Acres
52	Close to Longmont NW 1/4, Sec. 35, T3N, R69W	5 Acres
53	Near Table Mountain SW 1/4, Sec. 17, T2N, R70W SE 1/4, Sec. 18, T2N, R70W	15 Acres
54	SE 1/4, Sec. 7, T2N, R70W	5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
55	SW 1/4, Sec. 8, T2N, R70W	5 Acres
56	Prospect Road, County Road 24 SE 1/4, Sec. 15, T2N, R70W	5 Acres
57	East of Davis Reservoir SW 1/4, Sec. 3, T2N, R70W	5-10 Acres
58	Colorado 119 SE 1/4, Sec. 17, T2N, R69W	10-15 Acres
59	Colorado 119 SW 1/4, Sec. 9, T2N, R69W	5 Acres
60	Quail Road, County Road 20 NE 1/4, Sec. 15, T2N, R69W	5-10 Acres
61	Rogers Road NE 1/4, Sec. 12, T2N, R69W	5 Acres
62	Foothills Highway, Colorado 36 SE 1/4, Sec. 19, T2N, R70W	10-15 Acres
63	Niwot Road, County Road 34 NW 1/4, Sec. 33, T2N, R70W SW 1/4, Sec. 28, T2N, R70W	10-15 Acres
64	Sec. 32, T2N, R70W	10-15 Acres
65	Niwot Road, County Road 34 NW 1/4, Sec. 34, T2N, R70W	10-15 Acres
66	East Side of N 73rd Street	10-15 Acres
A	SW 1/4, Sec. 24, T2N, R70W	
B	NE 1/4, Sec. 24, T2N, R70W	
67	Lefthand Creek Sec. 19, T2N, R69W	5-10 Acres
68	Oxford Road, County Road 28 NW 1/4, Sec. 25, T2N, R69W	5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
69 A B	Jay Road, County Road 44 SW 1/4, Sec. 16, T1N, R70W SE 1/4, Sec. 16, T1N, R70W	15 Acres
70	Jay Road County Road 44 NE 1/4, Sec. 17, T1N, R70W	10-15 Acres
71	Twin Lakes SW 1/4, Sec. 11, T1N, R70W & SE 1/4, Sec. 10, T1N, R70W	5-10 Acres
72	Union Pacific Railroad SE 1/4, Sec. 16, T1N, R69W	5 Acres
73	Union Pacific Railroad, Lower Boulder Ditch NW 1/4, Sec. 14, T1N, R69W	5 Acres
74	Isabelle Road SE 1/4, Sec. 14, T1N, R69W	5 Acres
75	Boulder Creek SE 1/4, Sec. 1, T1N, R69W	5-10 Acres
76 A B	N 47th Street SW 1/4, Sec. 21, T1N, R70W NE 1/4, Sec. 20, T1N, R70W	5-10 Acres
77	Valmont Reservoir SW 1/4, Sec. 24, T1N, R70W	5 Acres
78	Valmont Drive, County Road 52 SE 1/4, Sec. 24, T1N, R70W	5-10 Acres
79	Colorado & Southern Railroad SE 1/4, Sec. 31, T1N, R69W	5-10 Acres
80	Hiram Prince Lake NE 1/4, Sec. 27, T1N, R69W	5 Acres
81	N 107th Street, Cottonwood Ditch SE 1/4, Sec. 22, T1N, R69W	5 Acres

APPENDIX F (Cont.)

Identifying Number On Habitat Map	General Location	Approximate Size
82	N. 95th Street NE 1/4, Sec. 5, T1S, R69W	5 Acres
83	South Broadway NW 1/4, Sec. 16, T1S, R70W	10-15 Acres
84	Baseline Reservoir	15 Acres
A	SW 1/4, Sec. 2, T1S, R70W	
B	NW 1/4, Sec. 11, T1S, R70W	
85	U.S. 36 SW 1/4, Sec. 13, T1S, R70W	5 Acres
87	S. 80th Street, County Road 25 SW 1/4, Sec. 7, T1S, R69W	5-10 Acres
88	Harper Lake SW 1/4, Sec. 7, T1S, R69W	5 Acres
89	S. 104th Street SW 1/4, Sec. 15, T1S, R69W	5-10 Acres
90	S. 104th Street NW 1/4, Sec. 22, T1S, R69W	10-15 Acres
91	Coal Creek Drive, County Road 25 SW 1/4, Sec. 26, T1S, R70W	5-10 Acres
92	Coal Creek Drive, Near Coal Creek Sec. 24, T1S, R70W	5-10 Acres
93	Broomfield Reservoir S 1/4, Sec. 36, T1S, R69W	5-10 Acres
94	Sheridan Boulevard NE 1/4, Sec. 36, T1S, R69W	5-10 Acres
95	Nissen Reservoir NW 1/4, Sec. 25, T1S, R69W	5-10 Acres
96	SW 1/4, Sec. 24, T1S, R69W	5 Acres

Source: Boulder County Land Use Department

MAPPING STUDIES USED IN DESIGNATING SIGNIFICANT WILDLIFE HABITAT IN THE DENVER REGION

Maps of Habitat Areas for Individual Species
Five-County Denver Region
Colorado Division of Wildlife, 1974, Updated in 1977
Scale 1:500,000

Wildlife Areas and Historical Sites
H.B. 1041 Technical Identification
Adams County Planning Department
Scale 1:48,000

Wildlife Habitat and Wetland Maps
Boulder County Planning Department
Scale 1:24,000
Maps for the following U.S.G.S. quadrangles:

- Berthoud
- Boulder
- Carter Lake Reservoir
- Eldorado Springs
- Erie
- Hygiene
- Lafayette
- Longmont
- Louisville
- Lyons
- Niwot

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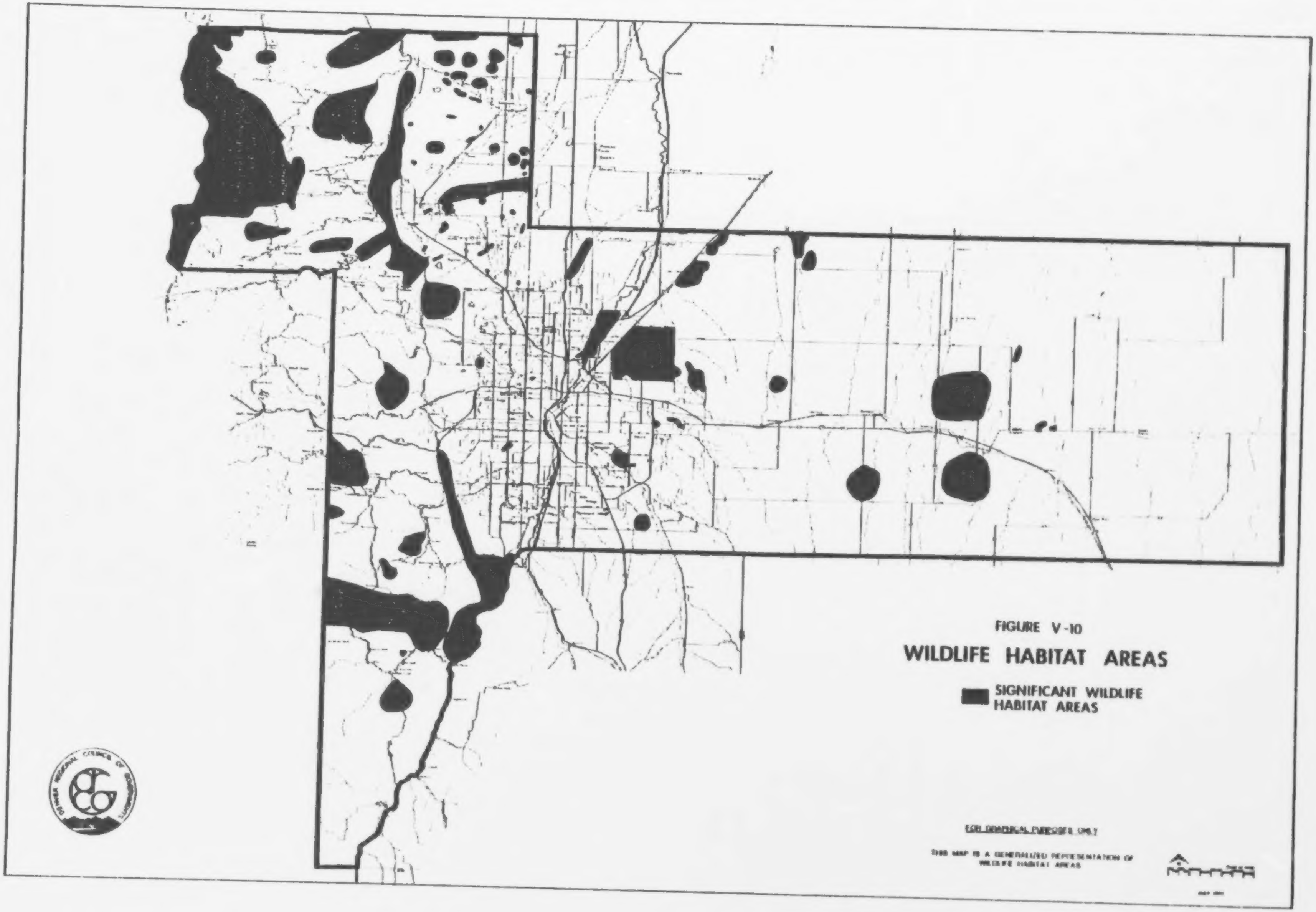

FIGURE V-10

WILDLIFE HABITAT AREAS

▇ SIGNIFICANT WILDLIFE HABITAT AREAS
FOR GRAPHICAL PURPOSES ONLY
THIS MAP IS A GENERALIZED REPRESENTATION OF WILDLIFE HABITAT AREAS

BIBLIOGRAPHY FOR SIGNIFICANT WILDLIFE HABITAT

Sources Available at DRCOG

WILDLIFE HABITAT REFERENCES

"Checklist of Colorado Wildlife" prepared by Colorado Department of Natural Resources Division of Wildlife - February 1975.

This checklist lists all the potential species that may occur in Colorado from the most simple life forms such as mollusks and crustaceans, through fish, amphibians, reptiles and birds to mammals.

"Colorado Breeding Data for Select Bird Species" (Second Revision - May 1976) by Walter D. Graul, Nongame Bird Specialist with the Colorado Division of Wildlife.

This report shows the breeding status of 112 species of birds, including raptors, in the State of Colorado. The data indicates, by regions within the State, if there is definite evidence of breeding (nesting) within the past 10 years, or if breeding is suspected by such evidence as presence of the species in an area in the summer. The data lists those species that are listed as threatened or endangered in Colorado. It also lists those species that do, in fact, have limited distributions in Colorado and species that occupy habitat that is particularly vulnerable to change. A description of the habitat type required by the different species is also included.

The Strategy of Today, for Wildlife Tomorrow, Volume I, A Strategic Plan for the Comprehensive Management of Colorado's Wildlife Resource. Colorado Division of Wildlife - 1974.

This report includes a discussion of the strategic plans for the management of most of the big game, small game, non-game, fish and bird species to be found in Colorado. Each species' strategic plan includes a discussion of the supply and demand, problems of the species and proposed strategies for future management.

Exploring Wildlife, Unit 1, Colorado Division of Wildlife, Cooperative Extension Service, Colorado State University, Ft. Collins, Colorado, 1972.

This report discusses the importance of wildlife, principles of wildlife management, different life zones or ecosystems that support wildlife, habitat improvement techniques, and wildlife laws and regulations. In addition, it includes sketches of many of the more common wildlife species which inhabit the State of Colorado.

Guidelines for Identification, Designation and Administration of Significant Wildlife Habitats and Shorelands of Major Publicly Owned Reservoirs, prepared by Colorado Division of Wildlife. October, 1974.

Guidelines for Identification, Designation and Administration of Significant Wildlife Habitats and Shorelands of Major Publicly Owned Reservoirs, prepared by Colorado Division of Wildlife. March, 1977.

This report was prepared for the Colorado Land Use Commission to meet the mandates of H.B. 1041. It includes guidelines for the identification of shorelands and significant habitat for terrestrial and aquatic wildlife species. It also includes guidelines for designation of these areas (once identified) under H.B. 1041.

An Ecosystem Guide for Mountain Land Planning - Level 1. Colorado State Forest Service, Colorado State University, by Dennis L. Lynch.

This report discusses 17 different types of ecosystems common to the mountain in Colorado. They are described individually in terms of vegetation, ecosystem dynamics, aesthetics, wildlife, soil and environmental hazards.

"Model Land Use Regulations - Chapter 8, Regulations for Significant Wildlife Habitat", Colorado Land Use Commission, March 26, 1976.

Environmental Study - Upper South Platte Unit - Colorado. Prepared for U. S. Department of Interior, Bureau of Reclamation, by International Engineering Co., Inc., Dames and Moore, Taliesin Associated Architects of the Frank Lloyd Wright Foundation; April, 1973.

This report has a good section on typical vegetation-mammal-bird species associations found in different habitats or ecosystems.

"The Relationship of Fish and Wildlife to the Denver Regional Transportation District" prepared by Harold W. Steinhoff for "Interim Technical Memorandum - Ecological Studies of the Regional Transportation District" by Development Research Associates/Wallace, McHarg, Roberts and Todd; December 31, 1971.

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This report discusses most of the wildlife in the region. It includes maps of the approximate ranges and distribution of many species within the state; however, most of that data is 10 to 15 years old. The data in this study has been outdated by the 1973 wildlife distribution maps prepared by the Colorado Division of Wildlife.

"Development Criteria to Keep Impact Within Acceptable Levels - Technical Memorandum 3-2" by Resource Planning Associates, Inc., Cambridge, Massachusetts; March 19, 1976.

This report has brief and general descriptions of the different habitats in the region and the general wildlife that they support.

"Basin Profiles - Environmental Element" by Resource Planning Associates, Inc.

These basin profiles (for 208 water quality planning program) consist of environmental descriptions of each of the major drainage basins in the region. Included in these descriptions are very brief discussions of wildlife and wildlife habitat in each basin.

Federal Register, Thursday, September 30, 1976, "Endangered and Threatened Wildlife and Plants," Department of the Interior, Fish and Wildlife Service.

Federal Register, Department of the Interior Fish and Wildlife Service "Endangered and Threatened Wildlife and Plants," Republication of List of Species, July 14, 1977, Part V.

"Wintering Areas and Winter Ecology of White-tailed Ptarmigan in Colorado," by Clait E. Braun, Richard W. Hoffman, and Glenn E. Rogers, Colorado Division of Wildlife, Special Report Number 38, published in March 1976.

This report discusses the wintering areas for ptarmigan and includes an atlas of known accessible white-tailed ptarmigan wintering areas in the state.

"Jefferson County Mountain Area Research Project - Volume 5 Attribute Reports," Section 2, Report 11, Habitat Suitability, Section 2, Report 13, Migration and Range Areas.

These reports are the documentation for Jefferson County's wildlife habitat mapping.

Memo from Darryl Todd, Colorado Division of Wildlife on "Major Fish Species Occurring in the Denver Regional Council of Governments' Area," January 18, 1977.

"Environmental Overview - Long Range Transit Development Analysis," Draft Report, April 1975, by Regional Transportation District, System Management Contractor.

"Endangered Species Act of 1973," 93rd Congress, House of Representatives, Report No. 93-740.

National Wildlife Federation Environmental Quality Index 1977.

This index analyzed increases or decreases in environmental quality in the area of wildlife, air, minerals, soil, forests, water, and development of land for urban uses.

Colorado Revised Statutes (C.R.S.) Chapter 33, Article 8 - Nongame and Endangered Species Conservation Act.

A Report on the Environmental Resources of Boulder County, Colorado, by Ann FitzSimmons, Boulder County Land Use Department, April 1977.

This report discusses the natural environment of Boulder County. It focuses on natural landmarks, soils, air quality, wildfire hazard areas and significant wildlife habitat.

SIGNIFICANT WILDLIFE HABITAT MAPS

Maps of Habitat Areas for Individual Species; Colorado Division of Wildlife, 1974.
Scale - 1:500,000

Maps for the following species:

Mule Deer	Overall Distribution
Mule Deer	Winter Distribution
Mule Deer	Distinct Biological Activity
White-tailed Deer	Winter Distribution
Antelope	Winter Distribution
Antelope	Distinct Biological Activity
Elk	Winter Distribution
Elk	Distinct Biological Activity
Bighorn Sheep	Overall Distribution
Bighorn Sheep	Winter Distribution
Bighorn Sheep	Distinct Biological Activity
Black Bear	Overall Distribution
Black Bear	Winter Distribution
Mountain Lion	Winter Distribution
Sharptail Grouse	Distinct Biological Activity
Blue Grouse	Overall Distribution
Pheasant	Overall Distribution
Pheasant	Distinct Biological Activity
Turkey	Overall Distribution
Turkey	Distinct Biological Activity
Wilson Snipe	Overall Distribution
Ptarmigan	Overall Distribution
Band-tailed Pigeon	Overall Distribution
Abert's Squirrel	Overall Distribution
Fox Squirrel	Overall Distribution
Snowshoe Hare	Overall Distribution
Prairie Falcon	Overall Distribution
Prairie Falcon	Distinct Biological Activity
Peregrine Falcon	Overall Distribution
Bald Eagle	Distinct Biological Activity
Golden Eagle	Overall Distribution
Golden Eagle	Distinct Biological Activity
Burrowing Owl	Overall Distribution
Bobcat	Overall Distribution
Ring-tailed Cat	Overall Distribution
Coyote	Winter Distribution
Coyote	Distinct Biological Activity
Badger	Overall Distribution
Red Fox	Overall Distribution
Red Fox	Distinct Biological Activity
Kit Fox	Overall Distribution
Kit Fox	Distinct Biological Activity

Gray Fox	Overall Distribution
Mink	Overall Distribution
Marmot	Overall Distribution
Cony	Overall Distribution
Prairie Dog	Overall Distribution

(These maps are only for the DRCOG region and Douglas County.)

Jefferson County Planning Department.
Maps are at a scale of 1:24,000 for the mountainous part of the county.
Critical Species Potential Habitat Map
They show potential habitat areas for Peregrine Falcon, Osprey, Boreal Forest Species, Prairie Grassland Species and Prairie Water species.

Habitat Suitability Map
Ranks areas as: poor
fair
good
excellent

Migration and Range Areas
Ranks areas for: low value
moderate value
high value

Adams County Planning Department
"Wildlife Areas and Historical Sites"
H.B. 1041 Technical Identification
Scale - 1 inch = 4,000 feet

Adams County Regional Park
2010 Conceptual Plan
Approximate Scale - 1 inch = 1,000 feet

Boulder County Planning Department
Wildlife Habitat and Wetlands Maps
Scale - 1 inch = 2,000 feet
Wildlife Habitat Maps for the following U.S.G.S. Quadrangles:

- Berthoud
- Boulder
- Carter Lake Reservoir
- Eldorado Springs
- Erie
- Hygiene
- Lafayette
- Longmont
- Louisville
- Lyons
- Niwot

Environmental Resources, Boulder, Colorado
Prime Wildlife Habitats
Boulder County Planning Department
Scale 1:96,000

PERSONAL CONTACTS FOR SIGNIFICANT WILDLIFE HABITAT INFORMATION

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REFERENCE SOURCES NOT PRESENTLY AVAILABLE AT DRCOG BUT WHICH SHOULD BE OBTAINED

Mammals of Colorado by Lechleitner.

This book includes in depth discussion of species habitat.

Mammals of Colorado by Armstrong.

This book includes studies of fossil records.

SAND, GRAVEL AND AGGREGATE RESOURCES

Criteria for Specification:

Specific combinations of landform units and resource classifications of sand and gravel, that have been identified as economically feasible for extraction, have been designated as environmentally significant natural resource areas in the Denver region.[1] Locations of specific rock formations which have been identified as being economically feasible for potential extraction of aggregate resources have also been designated as environmentally significant natural resource areas in the Denver Region. The specific combinations of landform units and resource classifications used to designate sand and gravel resource areas and the types of specific rock formations identified as aggregate resource areas are as follows:

Gravel:

Landform Unit	Resource Classification
Floodplain (F)	1. Gravel: relatively clean and sound
Stream-terrace Deposits (T)	1. Gravel: relatively clean and sound
	2. Gravel: significant silt, clay, incompetent rock and/or calcium carbonate (caliche)
Alluvial-fan Deposits* (A)	2. Gravel: significant silt, clay, incompetent rock and/or calcium carbonate (caliche)

*Only those A2 deposits located on the Rocky Flats site in northern Jefferson County have been designated as environmentally significant natural resources in this region.

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[1] Adams, Arapahoe, Boulder, Jefferson and Denver Counties.

Sand:

Landform Unit	Resource Classification
Stream-terrace Deposits (T)	3. Sands: includes sands ranging from coarse gravelly stream sands to fine-grained wind-deposited dune sands
Floodplain (F)	3. Sands: includes sands ranging from coarse gravelly stream sands to fine-grained wind-deposited dune sands
Valley-fill Deposits* (V)	3. Sands: includes sands ranging from coarse gravelly stream sands to fine-grained wind-deposited dune sands

*Only those valley-fill deposits located along Cherry Creek in Denver and Arapahoe Counties have been designated as environmentally significant natural resources in this region.

Quarry Aggregates:

Mapped areas of:

- carbonates
- volcanics and intrusives
- quartzite

Basis for Criteria:

The above criteria were chosen for delineation of significant sand, gravel and aggregate resources based upon studies and mapping prepared by the Colorado Geological Survey (CGS). These studies were authorized by the Colorado Revised Statutes, Chapter 34, Article 1, Part 3 entitled "Preservation of Commercial Mineral Deposits". This legislation was the result of H.B. 1529, and directed the Colorado Geological Survey to prepare a study locating and identifying the commercial mineral deposits (sand, gravel and quarry aggregate resources) in the populous counties of the State before July 1, 1974.

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H.B. 1529 also directs affected local governments to prepare master plans which will preserve valuable commercial mineral deposits for future extraction by zoning for mineral extraction or by prohibiting zoning changes that would prohibit extraction. This bill, along with the Open Mining Land Reclamation Act of 1973, are positive steps toward conservation and efficient utilization of mineral-aggregate resources within the state.

The resources of sand, gravel and quarry aggregate were mapped and classified by landform unit and resource classification. The landform unit refers to the physiographic, geologic unit which includes the resource. Landform units which were mapped for their content of these resources were floodplains, valley-fill deposits, stream-terrace deposits, upland deposits, alluvial fan deposits and wind-deposited (eolian) sand dunes. Each resource deposition was also assigned a resource classification to indicate its quality:

Classification 1 - Clean, sound, coarse gravel deposits.

Classification 2 - Coarse gravel deposits containing significant amounts of incompetent rock, silt, clay and calcium carbonate (caliche).

Classification 3 - Fine-aggregate sand deposits. This class includes sands ranging from coarse gravelly stream sands to find-grained wind-deposited dune sands.

Classification 4 - Areas of unevaluated aggregate deposits.

In developing this resource classification quality grading system, staff of the Colorado Geological Survey (CGS) interviewed representatives from many large sand and gravel companies to determine their definition of the current physical and economic limits of commercial sand and gravel deposits. Specific information obtained from these interviews about the physical definition of sand and gravel (the separation of sand and gravel sizes) was confirmed through subsequent literature research. Based on these interviews and literature searches, the CGS used the following criteria for identifying commercial sand, gravel and aggregate deposits:[2]

1) Five-acre tracts with at least 15 feet of gravel can be considered as an economically feasible deposit.

2) The maximum stripping ratio for commercial valley deposits approaches one unit of overburden for each

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[2] "Sand, Gravel and Quarry Aggregate Resources, Colorado Front Range Counties," Special Publication 5-A, CGS, 1974.

three units of the resource (1:3).

3) The maximum stripping ratio for terrace and upland deposits can be one unit of overburden to one unit of the resource (1:1).

4) Large tracts of high quality aggregate without overburden may be as little as 2 feet thick and still constitute a commercial deposit.

5) Commercial gravel deposits should contain a minimum of 30% gravel-size material by weight.

These basic criteria represent the general guidelines used by the CGS but were not the only standards used to determine commercial mineral deposits. Consideration was also given to such factors as the distance to market, supply and demand, local market conditions and possible future market locations.

The aforementioned landform mapping units of floodplain and stream-terrace deposits include the most commercial or economically feasible sand and gravel resource depositions. These depositions are younger in geologic age and are consequently the least altered (soundest), the least weathered, and the least cemented (less calcium carbonate or caliche). From a regional standpoint, the other landform units (upland, eolian, alluvial fan) are less significant for their commercial potential, but locally they may be quite important, especially in areas that lack high quality deposits. The upland depositions are generally older and consequently more weathered. Older depositions of gravel are commonly well cemented and difficult to disaggregate. The eolian deposits are also generally not of much regional consequence in terms of a commercial deposit. They generally contain more silt which is undesirable for commercial sand. A desirable sand deposit usually contains a better distribution of grain sizes including the coarser material associated with floodplain deposits.

The most significant commercial gravel areas in this region are along the South Platte River, Clear Creek, Boulder Creek and St. Vrain Creek. An additional significant gravel area is the alluvial fan depositions found on the Rocky Flats site in northern Jefferson County. Significant depositions of sand are largely located along Sand Creek, Cherry Creek and the South Platte River.

Potential quarry aggregate resources include the mapped units of carbonates, volcanics and intrusives, and quartzite. All of the potential quarry aggregate deposits which were mapped by the CGS are potentially commercial. The economic feasibility of extracting a deposit depends upon the supply, location, market, and demand for the aggregate, as well as existing and proposed land use, population distribution, existing roads and anticipated road maintenance requirements. The economic feasibility of potential quarry aggregate deposits may change over time as zoning, urban growth patterns, and market conditions change.

In the Denver Region, the potential quartzite quarry aggregate resources are in the far northwest corner of Jefferson County. The intrusive and volcanic depositions suitable for quarry aggregate are Ralston Dike, the Table Mountains, Valmont Dike near Boulder, and several dikes south of Lyons. Carbonate depositions of potential aggregate are located in the southwest corner of Douglas County.

The mapped units of potential quarry aggregates are composed mainly of andesite, monzonite and latite deposits. However, the Idaho Springs and other formations of large metamorphic and igneous crystalline complexes that compose much of the Front Range in this study area are suitable in some places for quarry aggregate. The gneisses and granites of the Idaho Springs formation are not as high quality as the andesite, monzonite and latite deposits that were mapped by the Colorado Geological Survey. Some quarries, however, do exist in the lower quality rock types of the Front Range. Interest may increase in opening new quarries in these lower quality rock formations for economic reasons due to proximity to market or if the higher quality quarry aggregate deposits become unavailable because of conflicting land use or unfavorable zoning or planning priorities.

The impact of future quarry aggregate production is generally based on economic determinants. Some of the factors which effect the location of quarry aggregate production are:

1) amount of currently available high quality gravel and the rate of depletion of those resources

2) the ease of access and proximity to potential markets and developing areas

3) the feasibility of economically importing gravel from areas outside of the Denver region

4) environmental considerations regarding the extraction site and adjacent existing and proposed future land uses.

There are many land use conflicts and problems linked with mineral extraction in close proximity to urbanized areas. These problems are the result of many factors. As urbanization covers more and more valuable aggregate deposits, extractors are forced to mine farther away from the principal markets. This causes increased costs in haulage which are eventually passed on to the consumer in terms of a higher cost for the material. In addition, as locations of resource deposits are encroached upon by expanding urbanization, areas of past and present mining that were located a good distance from the city are suddenly being surrounded by urban development which is generally incompatible with the noise, dust, and truck traffic associated with the mining operations. In recent years the mining industry has also been under attack from environmental groups and citizens who are concerned with the environmental effects of mining, the potential damage to nearby existing ecosystems, and the quality of site reclamation.

Sand, gravel and aggregate depositions have been classified as environmentally significant areas because they are natural resource areas. They are basic materials necessary for the construction of buildings and roads. Sand and gravel resources are also used in sewage treatment, water pollution and filtration, landscaping, and manufacturing. The main use of aggregate is for making concrete. However, it is also widely used as the base and sub-base of roadbeds. Because of all these uses, sand, gravel and aggregates are vitally important commodities which are essential for future urban development.

The value of production of sand and gravel in the Denver region has increased quite significantly in the past decade. In 1966, the value of sand and gravel production in the Denver region was approximately five million dollars and by 1973 the value had increased to approximately 22 million dollars. Appendix A shows the value of production of sand and gravel in this region, by counties, from 1966 through 1975. Jefferson and Adams County have been the leading producers of sand and gravel in this region over the past decade.

The ability of the counties in this region to supply sand and gravel has drastically changed over the past 4 decades. In 1935, Denver County supplied about 90% of the sand, gravel and aggregate requirements of Adams, Arapahoe, Denver and Jefferson Counties.

By 1950, output in Denver County had dropped to 20% of these 4 counties requirements.[3] This drastic decrease in output of sand, gravel and aggregate was largely due to exhaustion of the resource supply coupled with a loss of accessibility to other sources because they were covered over by urban development.

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[3] Urbanization and Its Impact on the Mineral Aggregate Industry in the Denver, Colorado Area by Matthew J. Sheridan, U.S. Dept. of the Interior Bureau of Mines, 1967, Information Circular 8320

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Presently, in the Denver region, Adams, Boulder and Jefferson Counties have sufficient resource reserves of sand, gravel and aggregates to meet future needs. However, all of these counties have experienced problems in integrating production of these resources with other conflicting land uses. The continual loss of potential aggregate resources to urban development is the primary problem in attempting to maintain an adequate resource supply to meet future sand, gravel and aggregate demands in these counties.

Arapahoe, Denver and Douglas Counties do not have significant reserves of gravel or quarry aggregate to meet future demands. Most of the aggregate needs of these counties will have to be met from outside of these counties.

Many of the municipalities in the Denver region have prepared mineral conservation and extraction plans in order to effectively deal with the use of resources located within their municipal boundaries. A list of municipalities in this region that have plans or ordinances for mineral resource areas has been prepared along with a brief summary of the plan and the content of any ordinances or policies which regulate future mineral extraction. This information is presented in a technical memorandum on the subject.[4]

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[4] Technical Memorandum on the Status of Mineral Conservation and Extraction Plans in the Denver Region, by Gail Hill, Comprehensive Planning Office, Denver Regional Council of Governments, January 1977

APPENDIX A

Value of Sand and Gravel Production 1966 - 1975

	1966	1968	1969	1970	1971	1972	1973	1974	1975
Adams Co.	1,170,814	2,828,427	2,287,925	6,125,287	7,101,181	4,507,142	7,104,173	4,855,394	5,617,030
Arapahoe Co.	1,188,001	1,161,069	942,896	1,397,251	3,358,252	2,303,401	2,455,425	2,191,391	2,139,561
Boulder Co.	137,315	1,627,417	1,791,894	1,049,627	2,055,910	2,803,068	2,658,098	2,094,537	1,281,032
Denver Co.	364,928	340,648	280,553	132,519	52,840	649,306	252,652	397,895	639,350
Jefferson Co.	2,574,199	3,330,815	3,311,365	4,347,289	5,090,997	6,493,833	10,288,962	11,450,473	7,460,657
DRCOG Region	5,435,257	9,288,376	8,621,633	13,051,973	17,659,180	16,756,750	22,759,310	20,989,690	17,137,630

SOURCE: Colorado Division of Mines - Summary of Mineral Industry
Activities in Colorado 1966, 1968-1975

MAPPING STUDIES USED IN DESIGNATING SAND, GRAVEL AND AGGREGATE RESOURCES IN THE DENVER REGION

Sand, Gravel and Quarry Aggregate Resources, Colorado Front Range Counties, by S.D. Schwochow, R. R. Shroba, and P.C. Wicklein.
Colorado Geological Survey, 1974
Special Publication 5-A
Scale 1:24,000
Maps for the following U.S.G.S. quadrangles:

- Allens Park
- Arvada
- Boulder
- Brighton
- Coal Creek
- Commerce City
- Eastlake
- Eldorado Springs
- Englewood
- Erie
- Fitzsimons
- Fort Logan
- Golden
- Gold Hill
- Hygiene
- Indian Hills
- Kassler
- Lafayette
- Littleton
- Longmont
- Louisville
- Lyons
- Morrison
- Nederland
- Niwot
- Parker
- Peoria
- Piney Creek
- Ralston Buttes
- Raymond
- Sable
- Strasburg SE
- Tungsten

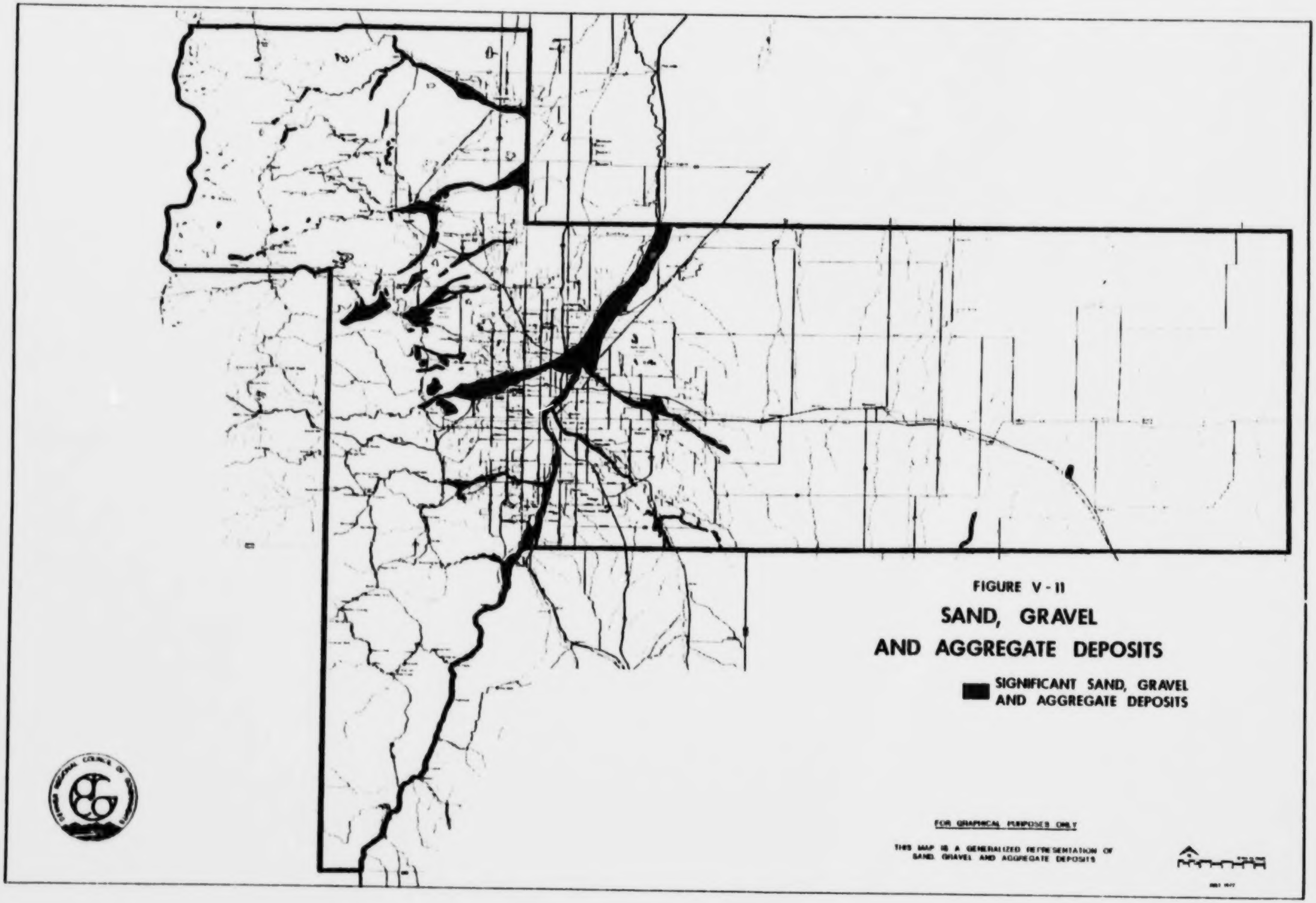

FIGURE V - II

SAND, GRAVEL AND AGGREGATE DEPOSITS

■ SIGNIFICANT SAND, GRAVEL AND AGGREGATE DEPOSITS

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF SAND, GRAVEL AND AGGREGATE DEPOSITS

BIBLIOGRAPHY FOR SAND, GRAVEL, AND AGGREGATE RESOURCES

Sources Available at DRCOG

SAND, GRAVEL, AND AGGREGATE REFERENCE RESOURCES

Sand, Gravel, and Quarry Aggregate Resources Colorado Front Range Counties - Special Publication 5-A by S. D. Schwochow, R. R. Shroba, and P. C. Wicklein; Colorado Geological Survey, Department of Natural Resources, 1974.

This report includes maps showing the locations of commercial deposits of sand, gravel and potential quarry aggregates. These deposits are classified according to landform unit and a resource classification which takes into account physical size and economic feasibility of the resource.

Front Range Urban Corridor, Colorado - Environmental Geologic and Hydrologic Studies - Map Showing Potential Sources of Gravel and Crushed-Rock Aggregate in the Greater Denver Area, by Donald Trimble and Harold Fitch; and in the Boulder-Fort Collins-Greeley Area by Roger Colton and Harold Fitch; 1974.

This study is composed of a map showing locations of potential gravel and aggregate resources in the front range corridor. The separations of gravel sizes shown in this study are based on scientific grain sizes and no separations for sand deposits are included.

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas - Special Publication No. 6 by W. P. Rogers, L. R. Ladwig, A. L. Hornbaker, S. D. Schwochow, S. S. Hart, D.C. Shelton, D. L. Scroggs and J. M. Soule, Colorado Geological Survey, Department of Natural Resources, State of Colorado, 1974.

This report was prepared for the Colorado Land Use Commission for the 1041 program. It contains a large section on mineral resources which includes sand, gravel and aggregate deposits.

"Model Land Use Regulations - Chapter 3 - Mineral Resource Area Regulations" - Colorado Land Use Commission.

H.B. 1529, Part 3, Preservation of Commercial Mineral Deposits.

Urbanization and Its Impact on the Mineral Aggregate Industry in the Denver, Colorado Area, by Matthew J. Sheridan, U.S. Department of the Interior, Bureau of Mines, 1967, Bureau of Mines Information Circular 8320.

This report discusses the background of the sand, gravel and aggregate industry in Denver, the location and reserves of these deposits, and examples of multiple-use and urbanization conflicts with the extraction of these aggregate materials in this region.

A Review of Selected Laws and Governmental Programs in Colorado, As Related to Mineral Resource Management and Surface Mining, Geological Survey Open-file Report #76-649, by Edgar A. Imhoff, Resource and Land Investigations (RALI) Program.

This report lists the existing local government regulatory activity under HB-1041 in the State of Colorado. Particular emphasis is given to regulation set forth by the City of Boulder and to that set forth by Weld County.

Weld County Mineral Resources Study, Volumes I and II, by Roy Jost, Weld County Planning Commission, July 1975.

Volume I is a study on mineral resources in the county. Volume II is the mineral extraction plan.

"A Master Plan for the Extraction of Sand and Gravel Resources," June 1975, prepared by the City of Wheat Ridge, Department of Community Development.

This plan discusses the location and type of sand, gravel and quarry aggregates in Wheat Ridge, which were identified through Colorado Geological Survey mapping. It also sets forth recommentations regarding mineral extraction and land use in these areas.

"Mineral Resources Element of the Broomfield Comprehensive Plan," prepared by the Broomfield Department of Planning and Community Development, adopted by the Broomfield City Council on April 14, 1975.

This publication includes a description of the sand, gravel and coal resources in Broomfield. It also states the City's objectives regarding mineral resources and the policies set forth for plan implementation.

"Drainage Course Plan for the Denver Region - Sand and Gravel Resources" Inter-County Regional Planning Commission, Denver, Colorado, October, 1961.

This report analyzes the sand and gravel resources in the Denver Region. It also includes estimates of the amount of original deposits, mined-out deposits, inaccessible deposits and remaining deposits.

Colorado Revised Statutes (C.R.S.), Chapter 34, Article 32 - "Colorado Open Mining Land Reclamation Act of 1973."

OTHER REFERENCES NOT PRESENTLY AVAILABLE AT DRCOG

Gravel Resources, Urbanization and Future Land Use, Front Range Urban Corridor, Colorado. U.S. Dept. of Interior, Geological Survey, Open-file Report No. OF-74-178, by James M. Soule, Calculation of Reserves, by Harold R. Fitch.

This report assesses the gravel needs of markets in the Front Range Urban Corridor until the year 2000 based on forecasts of population and urbanization. In addition, a method for computing gravel reserves in individual markets was developed.

SAND, GRAVEL AND AGGREGATE MAPS

Map Showing Potential Sources of Gravel and Crushed Rock Aggregate,
  Front Range Urban Corridor, Colorado
  Maps for:
    Greater Denver Area, by Donald E. Trimble and Harold R. Fitch,
      Map I-855-D.
    Boulder-Fort Collins-Greeley Area, by Roger B. Cotton and
      Harold R. Fitch, Map I-856-A.
  U.S.G.S. 1974, Scale - 1:100,000

Sand, Gravel and Quarry Aggregate Resources
  Colorado Front Range Counties, by S.D. Schwochow, R. R. Shroba,
    and P. C. Wicklein
  Colorado Geological Survey, 1974, Special Publication 5-A
  Maps for the following counties at a Scale - 1:250,000:
- Larimer
- Weld
- Boulder
- Adams
- Arapahoe
- Denver
- Jefferson
- Douglas
- El Paso
- Pueblo

Maps for the following U.S.G.S. quadrangles at a Scale - 1:24,000:
- Allens Park
- Arvada
- Bennett
- Boulder
- Box Elder School
- Brighton
- Byers
- Byers S.W.
- Coal Creek
- Commerce City
- Deckers
- Deer Trail
- Eastlake
- Eldorado Springs
- Englewood
- Erie
- Fitzsimons
- Ft. Logan
- Golden
- Gold Hill
- Highlands Ranch
- Horse Creek
- Hygiene
- Indian Hills
- Kassler
- Lafayette
- Leader
- Leader N.W.
- Leader S.E.
- Leader S. W.
- Littleton
- Living Springs
- Longmont
- Louisville
- Lyons
- Manila
- Mile High Lakes
- Morrison
- Nederland
- Niwot

Parker	Raymond
Peoria	Roper School
Pine	Sable
Piney Creek	Strasburg S.E.
Platte Canyon	Tungsten
Ralston Buttes	Ward

Mineral Resources Map
Boulder County Planning Department, 1976
Scale - 1:24,000
Maps for the following U.S.G.S. quadrangles:
Erie
Louisville

Natural Resources Map No. One
Sand, Gravel and Coal
H.B. 1041 Technical Identification
Adams County Planning Department
Scale - 1:48,000
Set of two maps

Sand, Gravel and Quarry Aggregates Resources Map
Arapahoe County Planning Department
Scale - 1:24,000
Set of four maps

Jefferson County Computer Minerals Map 1976

This set of computer printout maps shows the mapping published in 1974 by the Colorado Geologic Survey on sand, gravel and quarry aggregate resources in Jefferson County. These computer printout maps are associated with overlay maps at a scale of 1:24,000.

PERSONAL CONTACTS FOR SAND, GRAVEL AND AGGREGATE DEPOSITS INFORMATION

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COAL RESOURCES

BIBLIOGRAPHY FOR HISTORICAL PLACES

Sources Available at DRCOG

HISTORICAL PLACES REFERENCES

Guidelines for the Identification and Designation of Historical, Natural, and Archaeological Resources, by the State Historical Society of Colorado, 1974.

This report was prepared by the State Historical Society of Colorado to assist counties in the identification and designation of historic, natural and archeological resources under the HB 1041 program. It sets forth criteria used to identify places of historic, natural and archeological significance.

"Statewide Inventory of Historic Sites" - Updated through March 1977, by the State Historical Society of Colorado.

This report includes a listing and description of all historic structures, sties and districts which are on the State or National Register of Historic Places in the Counties of Adams, Arapahoe, Boulder, Clear Creek, Denver, Douglas, Gilpin and Jefferson.

"List of Designated Denver Landmarks and Entries to the National Register of Historic Places," City and County of Denver Department of Planning.

This listing shows the name and location of historic sites in Denver as well as the effective date of designation of the site as a Denver Landmark.

"Inventory of Archaeological Sites," Office of the State Archaeologist, State Historical Society of Colorado.

This inventory lists archaeological sites in the Counties of Adams, Arapahoe, Boulder, Denver, Douglas, Jefferson and Weld.

"Preservation and Planning," by Lachlan F. Blair in "Planning and Public Policy," Volume 1, Number 2, Spring 1975, Bureau of Urban and Regional Planning Research, University of Illinois at Urbana-Champaign.

This article addresses the objectives of historic preservation and planning and discusses the role of historic preservation in today's comprehensive planning process.

"Model Land Use Regulations - Chapter 7, Historical and Archaeological Resource Area Regulations," by the Colorado Land Use Commission.

A Report on the Environmental Resources of Boulder County, Colorado, Boulder County Land Use Department by Ann R. FitzSimmons, April 1977.

This report includes a discussion of historical sites, natural landmarks and archaeologic sites in Boulder County. It also includes a listing of sites of historic significance identified by state and local agencies and local historical societies.

House Bill #1561 Concerning Property of Historic Significance, and Providing for a State Register of Historic Properties, Colorado State Legislature.

Historic Preservation Overview, State Planning and Management Region III, prepared by Fred Wolfe, Denver Regional Council of Governments, January 1976.

This report presents an overview of historic preservation in State Planning and Management Region III. It discusses the development of historic preservation legislation and the benefits of historic preservation. It also includes a map and listing of historic structures, sites and districts in Region III along with a brief description of each site.

HISTORICAL PLACES MAPS

Historic Preservation
Denver Regional Council of Governments
Scale 1" = 2 miles

Wildlife Areas and Historical Sites
HB 1041 Technical Identification
Adams County Planning Department; Technical Source, State Historical Society
Scale 1:48,000

Historical Sites
Jefferson County Planning Department
Set of 7 maps
Scale 1:24,000
Maps show:

Historical sites of State and/or local interest, and national interest (National Historic Register), historic areas or districts, historic roads and trails, historic railroads

Map Showing Outstanding Natural and Historic Landmarks in the Greater Denver Area, Front Range Urban Corridor, Colorado, by Brent N. Petrie, U.S. Geological Survey, 1976, Map I-856-F, Scale 1:100,000.

Historic Trail Map of the Greater Denver Area, Colorado, by Glenn R. Scott, U.S. Geological Survey, 1976, Map I-856-G, Scale 1:100,000.

Map of Pioneer Trails, Stage Stops and Areas With a View in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry, U.S. Geological Survey, 1973, Map I-770-M, Scale 1:24,000.

Map Showing Some Points of Geologic Interest in the Morrison Quadrangle Jefferson County, Colorado, by Glenn R. Scott, U.S. Geological Survey, 1972, Map I-790-E, Scale 1:24,000.

PERSONAL CONTACTS FOR HISTORICAL PLACES INFORMATION

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HISTORIC PRESERVATION ORGANIZATIONS IN THE DENVER REGION

Adams County

Adams County Historical Society
Dr. Roy H. Carlson
11176 Pearl Street
Northglenn, Colorado 80233

Commanche Crossing Historical Society
Homestead House
Living Springs School
Pioneer Museum
c/o Ms. Emma Mitchell
Route 1, Box 75
Strasburg, Colorado 80136

Arapahoe County

Aurora Historical Commission
Mr. John L. Beeken, Chairman
P.O. Box 627
Aurora, Colorado 80010

Colorado Military Historians
3966 South Mariposa
Englewood, Colorado 80110

Colorado Corral of the Westerners
Mr. John Albright, Secretary
7942 South Lamar Court
Littleton, Colorado 80123

Littleton Area Historical Society
Littleton Historical Museum
6028 South Gallup
Littleton, Colorado 80120

Boulder County

Boulder Historical Society
Mr. Laurence T. Paddock, President
c/o Dailey Camera
P.O. Box 591
Boulder, Colorado 80302

Historic Boulder, Inc.
P.O. Box 1545
Boulder, Colorado 80302

Longmont Museum
302 Kimbark
Longmont, Colorado 80501

St. Vrain Historical Society
P.O. Box 705
Longmont, Colorado 80501

Denver

Colorado State Museum
200 14th Avenue
Denver, Colorado 80203

Denver Landmark Preservation Commission
Edward D. White, Jr., Chairman
c/o Denver Planning Office
Room 400
1445 Cleveland Place
Denver, Colorado 80202

Denver Museum of Natural History
City Park
Denver, Colorado 80206

Forney Transportation Museum
1416 Platte
Denver, Colorado 80202

Historic Denver, Inc.
1059 9th Street
Denver, Colorado 80204

Police - Sheriffs - Firemen Historical Museum
1249 Bannock Street
Denver, Colorado 80204

West Denver Auraria Historical Society
317 West 4th Avenue
Denver, Colorado 80204

Jefferson County

Jefferson County Historical Society
Mr. Wallace Howell
Route 3, Box 400
Golden, Colorado 80401

Arvada Historical Society
P.O. Box 419
Arvada, Colorado 80001

Buffalo Bill Museum
P.O. Box 950, Route #5
Golden, Colorado 80401

Colorado Railroad Museum
P.O. Box 641
Golden, Colorado 80401

Golden Landmark Association
1200 Illinois Street
Golden, Colorado 80401

Pioneer Museum
911 10th Street
Golden, Colorado 80401

Judge Johnson Cabin Museum
Parks and Recreation Department
City of Wheat Ridge
P.O. Box 610
Wheat Ridge, Colorado 80033

Save Our Soddy
c/o Boyd Kraemer, Director
Parks and Recreation Department
City of Wheat Ridge
P.O. Box 610
Wheat Ridge, Colorado 80033

GLOSSARY

AGGREGATE - Rock materials used for mixing with a cementing material to form concrete and associated construction materials.

ALLUVIAL FAN - A gently sloping cone of alluvium (sediments) deposited at the mouth of a tributary stream that emerges from a hilly or mountainous area.

ALLUVIUM - The mass of clay, silt, sand, gravel and other sediment deposited by a stream or other body of running water.

ALPINE - Life zone made up of elevated slopes above the timberline and characterized by small plants, mosses and lichens. Generally above 11,500 ft. elevation in Colorado.

ANTHRACITE - The metamorphic rocks produced by the compression of bituminous coal; "hard" coal. It has a higher value and BTU than other coal.

ANTICLINAL TRAP - Place where water, petroleum, and natural gas accumulate in up-arched strata provided the structure contains reservoir rocks in proper relation to source beds and is capped by an impervious barrier.

AQUIFER - An underground geological formation which contains sufficient saturated permeable material that stores, transmits, and dispenses groundwater.

AQUIFER RECHARGE - The process whereby precipitation or water from streams or lakes seeps underground into permeable water bearing formations (aquifers) to replenish their water supply.

ARTESIAN WATER - Water that is under pressure when tapped by a well and is able to naturally rise above the level at which it is first encountered.

ATTERBERG LIMITS - Certain properties of clay soils that are dependent upon water content. The three most common limits are: the liquid limit, the plastic limit, and the shrinkage limit. These represent the water content as a percent of dry soil weight at transitions from liquid to plastic behavior from plastic to solid, and the water content below which further loss of water by evaporation does not result in a reduction in volume of the soil. These soil parameters are determined by standard laboratory tests.

AVALANCHE - The rapid downslope movement of snow, ice and associated debris such as rocks and vegetation which generate such a force as to directly or indirectly damage or destroy most man-made structures.

BEDDING PLANE - A plane that separates the different layers in a sedimentary rock sequence. Each bedding plane marks the termination of one deposit and the beginning of another of different character such as the surface separating a sand bed from a shale layer. A rock tends to separate or break readily along bedding planes.

BENTONITE - Layers of white or yellow clay containing a mineral called montmorillonite which is water absorbing and highly swelling.

BIG GAME SPECIES - Wildlife grouping which includes the large hoofed animals, bears and mountain lion in Colorado.

BITUMINOUS COAL - The sedimentary rock composed of a compressed mass of partially decayed vegetable matter; "soft" coal containing about 80 percent carbon and 10 percent oxygen.

BRECCIA - Crushed, angular rock imbedded in a fine grained matrix (such as sand or clay).

CALICHE - A deposit of calcium carbonate laid down in near-surface pores of soil as underground water is drawn to the surface and evaporated.

CATION - An ion which has more protons than electrons; a positively charged ion.

COLIFORM BACTERIA - A group of bacteria that reside in the intestines of many vertebrates. The presence of coliform bacteria is used as an indication of the level of fecal contamination of a water supply.

COLLUVIUM - Any loose, poorly-sorted mass of soil or rock debris of all particle sizes moved by the pull of gravity alone. Colluvium is usually formed at the base of a steep slope.

CONGLOMERATE - Rocks made up of rounded fragments that correspond in size to gravel or pebbles formed from accumulations of minerals and rocks derived either from erosion of previously existing rock, or from the weathered products of these rocks.

CRETACEOUS - Geologic time period that refers to the time from approximately 70 million years ago to 125 million years ago.

DENVER BASIN - An asymmetrically spoon-shaped geologic structure that underlies the metropolitan Denver area extending from near Greeley southward to Colorado Springs and east/west from the foothills toward the general area of Byers in the plains. Most of the energy resources (oil, gas, coal) in the Denver region are located within the Denver Basin.

EARTHQUAKE - A naturally produced tremor or shaking of the earth that is volcanic or tectonic in nature.

ECOSYSTEM - The complex of a community of plants and animals and the associated non-living environment functioning together as an ecological unit in nature.

ENDANGERED SPECIES - A species whose prospects for survival and reproduction within an area are in jeopardy, or is likely to become so within the foreseeable future. It is basically in danger of extinction throughout all or a significant portion of its range.

EOCENE - Geologic time series in the Tertiary time period, refers to the time period from approximately 40 million years ago to 60 million years ago.

EOLIAN - Borne, deposited, formed or eroded by the wind.

EPICENTER - The point of seismic disturbance on the earth directly above an earthquake's hypocenter.

EROSION - The wearing away of rock or soil and the movement of the resulting particles by wind, water, ice, or gravity.

FAULT - A rock fracture along which rock blocks have moved past one another as a result of stresses and movement in the earth's crust.

FIRE CHIMNEY AREAS - Ravines characterized by steep slopes (greater than 30%) and dense vegetation. Such ravines generally confine the smoke and heat along with natural convection currents and thus cause rapid, upward increases in fire spread and intensity.

FLOODPLAIN - An area in and adjacent to a river, stream or lake which is subject to flooding as the result of the occurrence of an intermediate regional flood.

GASIFICATION - Process whereby coal is reacted with hydrogen under heat and pressure to produce methane gas.

GEOLOGIC FORMATION - The ordinary unit of geologic mapping recognizable by field criteria consisting of a large, persistent and mappable strata of predominately one kind of rock.

GOUGE - Clay and finely divided rock fragments.

HOGBACK - A symmetrical, steeply sloping ridge that is the eroded edge of a hardrock layer which dips downward at a steep angle.

HOLOCENE - Recent geologic time series in the Quaternary time period. Refers to the time period from approximately 10,000 years ago to the present.

HYDRAULIC CONDUCTIVITY - The capacity of an aquifer to transmit water.

HYDROCARBONS - A compound of hydrogen and carbon that burns in air to form water and oxides of carbon. There are many hydrocarbons. The simplest, methane, is the chief component of natural gas. Petroleum is a complex mixture of hydrocarbons.

HYDROCOMPACTION - A property of some dry unconsolidated deposits to undergo, after wetting, spontaneous compaction, settling and cracking. Commonly this occurs in areas that are normally dry and then subjected to abnormal wetting.

HYDROSTATIC HEAD - A measure of pressure at a given point in a liquid in terms of the vertical height of a column of the liquid which would produce the same pressure.

HYPOCENTER - The location where the movement or energy release initiates during an earthquake.

IGNEOUS ROCK - A rock that has solidified from molten material that originated within or just beneath the earth's crust.

INTERMEDIATE REGIONAL FLOOD - A flood having a one percent probability or an average frequency of occurrence on the order of once in 100 years although the flood may occur in any year.

JOINTS - A fracture in a rock mass along which there has been no vertical movement in the rocks on either side of the fracture plane.

KAOLIN - A light clay rock formed by the decomposition of rocks of high feldspar content which is of economic importance for use in the manufacture of porcelain and bricks, and as a source of alumina. It contains high percentages of the clay mineral kaolinite.

LADDER FUELS - Fuels arranged between two separate fuel strata, such as between the forest floor and tree conopies, which provide vertical continuity and thereby easy fire spread in a vertical direction.

LANDSLIDES - The rapid downslope movement of a mass of rock and earth, usually ruptured from a zone of weakness which separates the slide material from the more stable underlying material, which is so adverse to past, current or foreseeable construction or land use as to constitute a significant hazard to human safety and property.

LIFE ZONE - A climatic zone or belt which is characterized by a certain group of plants and animals.

LIGNITE - A low grade coal with about 70 percent carbon and 20 percent oxygen which is intermediate between peat and bituminous coal. It is also called "brown coal."

LIQUEFACTION - Process by which coal is converted directly into liquid fuel.

LOESS - A wind-deposited unstratified, unconsolidated, blanket-like surficial deposit consisting primarily of silt, and which is generally yellowish-brown in color. Loess is generally found covering gentle hillslopes and uplands. Undisturbed loess may stand unsupported in very steep or vertical faces.

Mcf - Thousand cubic feet.

METAMORPHIC - Refers to processes that change the form and composition of rocks and minerals under conditions of heat and pressure.

MIOCENE - Geologic time series in the Tertiary time period. Refers to the time period from approximately 10 million years ago to 25 million years ago.

MITIGATE - To make less severe.

MONTANE - Life zone made up of relatively moist cool upland slopes below the timberline and characterized by the presence of large evergreen trees as a dominate life form. It is generally located between 8,000 feet and 10,500 feet elevation in Colorado.

MUDFLOWS - A mudflow is a geologic phenomenon whereby mud and sediment flows rapidly down the mountain watershed usually due to exceedingly high runoff, rainfall or snowmelt.

NATIONAL REGISTER OF HISTORIC PLACES - A list of historical, architectural and archaeological places that have recognized value in the history of the locale, the state, or the nation. Entries into the National Register of Historic Places are evaluated by a specific set of criteria and then documented by descriptions and photographs of the site which are kept in Washington, D. C. by the National Park Service.

NON-GAME SPECIES - Wildlife species which are not classified as sport game wildlife. Includes all threatened and endangered species.

OLIGOCENE - Geologic time series in the Tertiary time period. Refers to the time period from approximately 25 million years ago to 40 million years ago.

ONE HUNDRED YEAR FLOOD - Common term for intermediate regional flood.

OUTCROP - The part of bedrock or of an unconsolidated deposit that appears at the surface of the ground.

OVERBURDEN - Soil and rock material overlying a deposit of useful geological materials (such as a mineral deposit or coal).

PALEOCENE - Geologic time series in the Tertiary time period. Refers to the time period from approximately 60 million years ago to 70 million years ago.

PLEISTOCENE - Geologic time series in the Quaternary time period. Refers to the time period from approximately 10,000 years ago to 1-2 million years ago.

PLIOCENE - Geologic time series in the Tertiary time period. Refers to the time period from 1-2 million years ago to 10-11 million years ago.

PNEUMATIC FILLING - Transport and placement of fill material by air pressure. Pneumatic filling is one technique for mitigation of subsidence hazard areas.

POTENTIOMETRIC SURFACE - An imaginary surface connecting levels to which water would rise in tightly cased wells from a given point in an aquifer. It represents the artesian pressure or hydraulic head throughout all or part of an artesian or confined aquifer.

PRECAMBRIAN - Geologic time period which refers to the time approximately 600 million years ago and older.

PRIME FARMLAND - That land best suited for producing food, feed, forage, fiber and oilseed crops and is also available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land but not urban buildup land or water). It has the soil quality, growing season and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods.

QUATERNARY - Geologic time period that refers to the time from approximately the last 1-2 million years to the present.

RAPTORS - Birds of prey such as eagles, falcons, hawks and owls.

RESIDIUM - Unconsolidated and partly weathered material that is presumed to have developed in place from weathering of the consolidated rock on which it lies.

RICHTER SCALE - A logarithmic scale widely used to indicate the magnitude of the energy released by an earthquake. Shock waves with a Richter value of less than 5.0 are only local in their effects and do little damage. Shocks between 5.0 and 7.0 are moderately intense and may seriously damage certain kinds of man-made structures. Any seismic shock of 7.0 or above is considered to be a major earthquake, one of great destructiveness.

RIPARIAN - Related to or located along the bank or shoreline of a natural watercourse.

ROCKFALL - The downslope movement by means of freefall, rolling, bouncing or sliding of large rock fragments which generates such a force as to damage or destroy most man-made structures.

RUNOFF - Water from atmospheric precipitation that moves across the land surface.

SCARP - An elongated steep slope that bounds an elevated block of the earth's crust.

SEDIMENTARY ROCK - Rock formed from accumulations of sediment, which may consist of rock fragments of various sizes, the remains or products of animals or plants, the product of chemical action or evaporation, or mixtures of these. Sedimentary rocks cover about 75 percent of the land area of the world.

SEDIMENTATION - The process by which mineral and organic matter is laid down.

SEISMIC - Pertaining to earthquakes or earth vibrations, including those that are man-made, e.g., explosions, underground nuclear blasts.

SEPTIC LEACHATE - The liquid that has percolated through the soil or other media in a septic system leach field and has extracted dissolved or suspended materials from it.

SHRINK-SWELL SOIL - Soil and rock which contain clay and which expands or swells to a significant degree upon wetting and which shrinks upon drying.

SLASH - Vegetative debris left after cutting or clearing operations in forest or brush areas.

SMALL-GAME SPECIES - Wildlife grouping which includes game birds, rabbits and hares, fox squirrels and band-tailed pigeons in Colorado.

SOIL CAPABILITY CLASSIFICATION - The grouping of soils to show, in a general way, their suitability for most kinds of farming. It is a practical classification based upon the physical limitations of the soils, the risk of damage to the soils (mainly soil loss due to erosion) when they are used for farming, and the way the soils respond to treatment.

SOIL CREEP - The slow movement of the soil mantle downslope by the pull of gravity which is usually accelerated by lubrication from excessive rainfall or runoff.

SOIL SLUMP - The rapid downslope movement of large portions of the soil mantle by the pull of gravity which is usually accelerated by lubrication from excessive rainfall or runoff.

SOLUM - The altered layer of soil above the parent material.

STANDARD PROJECT FLOOD - The flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographic area in which the drainage basin is located, excluding extremely rare combinations.

STRATIGRAPHIC TRAP - An oil or gas-bearing sedimentary rock in which the oil or gas is confined because of variation in permeability of the reservoir rock, or the termination of an inclined reservoir formation on the up-dip side.

STRIPPABLE COAL RESOURCES - Generally coal that is a minimum of 2 feet thick with an overburden thickness of 150 feet or less.

SUB-ALPINE - Life zone constituting high upland slopes immediately below the timberline and characterized by spruce and fir. Generally between 10,500 feet and 11,500 feet elevation in Colorado.

SUBBITUMINOUS COAL - Coal of a lower rank than bituminous coal but of higher rank than lignite.

SUBSIDENCE - A process characterized by the downward displacement of surface material caused by natural phenomenon such as removal of underground fluids, natural consolidation, or dissolution of underground minerals, or by man-made phenomenon such as underground mining.

TALUS - A sloping mass of rock fragments that have fallen from the face of a steep slope and that have accumulated at the base of that slope.

TECTONICS - A branch of geology concerned with structure, especially with folding and faulting.

TERTIARY - Geologic time period that refers to the time from approximately 2 million years ago to 70 million years ago.

THREATENED SPECIES - A species is rated as threatened when the individuals constituting the species population exist in such small number or are so restricted in their general distribution that they may become endangered within the foreseeable future throughout all or a significant portion of its range.

WATERSHED - That area that supplies runoff to the streams within its drainage basin.

WILDFIRE HAZARD AREA - An area which is subject to a wildfire (an uncontrolled fire burning in vegetation, structures, or other improvements) which is so adverse to past, current or foreseeable construction or land use as to constitute a significant hazard to public health, safety or to property.

WILDLIFE HABITAT - A geographical area containing those elements of food, water, cover, space and general welfare in a combination and in quantities adequate to support a species for at least a portion of the year; areas used by wildlife for range, feeding and production.

YARMOUTH - Geologic time division related to glaciation (interglacial period). Refers to time period approximately 600,000 to 700,000 years ago.

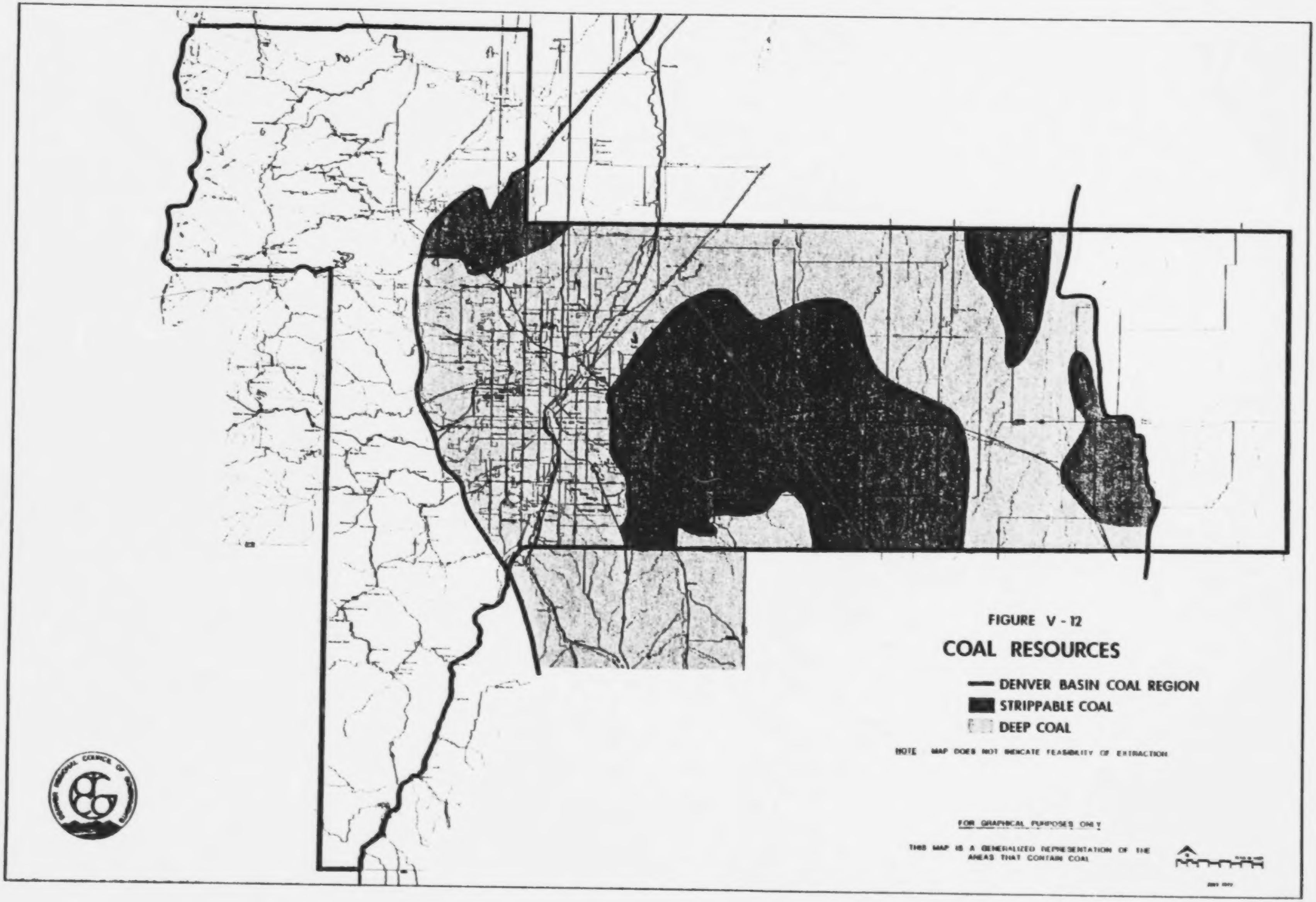
FIGURE V - 12

COAL RESOURCES

DENVER BASIN COAL REGION
STRIPPABLE COAL
DEEP COAL

NOTE MAP DOES NOT INDICATE FEASIBILITY OF EXTRACTION

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF THE AREAS THAT CONTAIN COAL

BIBLIOGRAPHY FOR COAL RESOURCES

Sources Available at DRCOG

COAL REFERENCE RESOURCES

Coal Resources of Colorado, Geological Survey Bulletin 1072-C, by E.R. Landis, U.S. Department of the Interior, 1959.

This report generally describes the location and quality of coal in the State of Colorado. In addition, it includes statistical data on measured and indicated, and inferred original coal reserves on a township/range basis. This data is given for thickness of coal bed and depth of overburden.

Analysis of the Coal Industry in Boulder-Weld Coalfield, Colorado, by Raymond L. Lowrie, 1966, U.S. Department of the Interior, Bureau of Mines, Report of Investigation 6726.

This report describes the physical as well as economic characteristics of the Boulder-Weld coalfield. The actual estimates of the coal reserves in this report are adapted from the USGS Geological Survey Bulletin 1072-C by E.R. Landis.

"A Preliminary Report on a Zone Containing Thick Lignite Beds - Denver Basin, Colorado" by Paul E. Soister, 1974, U.S. Department of the Interior, Geological Survey Open-file report #74-27.

This report discusses the zone of lignite coal in the Denver Basin. Historical mining activity in this zone is analyzed individually by each mine. It also includes a map showing, on a township basis, the general thickness of the coal bed and whether the bed is within 250 feet of the ground surface or between 250 to 1000 feet of the ground surface.

Strippable Coal Resources of Colorado -- Location, Tonnage, and Characteristics of Coal and Overburden, by Charles N. Speltz, 1976, U.S. Department of the Interior, Bureau of Mines, Information Circular 8713.

This report discusses the coal in Colorado which has potential for strip mining (greater than 2 feet thick lignite which has less than 150 feet overburden as defined in this report).

Coal Resources of the United States, January 1, 1974, Geological Survey Bulletin 1412, by Paul Averitt, Department of the Interior, U.S. Geological Survey.

This report discusses the distribution of coal resources throughout the nation. It also discusses coal production from selected coal beds as well as costs and uses of coal. In addition this report looks at past and present production of coal throughout the world.

"Coal Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey" Geological Survey Bulletin 1450-B.

This report contains the classification systems and definitions used by the U.S.G.S. and U.S. Bureau of Mines in classifying coal resources and coal reserves. Also included are the criteria for identification and classification of coal reserves and resources.

Guidelines and Criteria for Identification and Land Use Controls of Geologic Hazard and Mineral Resource Areas by W.P. Rogers, L.R. Ladwig, A.L. Hornbaker, S.D. Schwochow, S.S. Hart, D.C. Shelton, D.L. Scroggs, and J.M. Soule, Special Publication No. 6, Colorado Geological Survey, 1974.

This report was prepared for the Colorado Land Use Commission for the 1041 program. It defines mineral resource areas and discusses mineral production throughout the state.

Projects to Expand Fuel Sources in Western States - Survey of Planned or Proposed Coal, Oil Shale, Tar Sand, Uranium and Geothermal Supply Expansion Projects and Related Infrastructure, in States West of the Mississippi River (as of May 1976), by John S. Corsentino, Intermountain Field Operations Center, Denver, Colorado, U.S. Department of Interior, Bureau of Mines, Bureau of Mines Information Circular 8719.

This report includes a listing of future fuels-related projects in each state in the nation. These projects are listed by their location in counties.

"Coal Mine Inspection Department Combined Annual Reports 1941-1942-1943", State of Colorado.

This report includes information on coal production from individual mines. This data is presented on a county basis.

"Bedrock Geology of the Louisville Quadrangle, Colorado" by Frank D. Spencer, U.S.G.S., 1961.

The text associated with the geologic map indicates that coal beds exist in the Laramie formation which covers a goodly part of this quadrangle.

A Report on the Environmental Geology of Boulder County, Colorado, by Thomas C. Gray, County Geologist, Boulder County Land Use Department, February 1977.

This report includes a discussion on the recoverable coal reserves in the county.

"Gas from Coal" by Victor D. Chase in "Popular Science", January 1977.

This article discusses the process of coal gasification. In this process coal is reacted with hydrogen to produce methane.

"Modeling Depletion In A Mineral Industry: The Case of Coal", by Martin B. Zimmerman in The Bell Journal of Economics, Spring 1977, Vol. 8 No. 1.

The article discusses the long-run marginal cost of producing a depletable resource. It also discusses policy issues dealing with the development of coal resources.

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This report discusses production of coal in Colorado and describes each of the coal regions in the State.

COAL REFERENCE RESOURCES NOT AVAILABLE AT DRCOG

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This report includes statistical data from chemical analyses of coal samples taken from the Denver basin and other areas of coal resources in Colorado and New Mexico.

Colorado Energy Resources Handbook, Volume 1: Coal, prepared by Colorado Energy Research Institute, published by Colorado School of Mines by J.G. Morse and D.H. Hebb, June 1976.

This report discusses the nature of different types of coal, the location of coal resources in Colorado, production of coal in Colorado, and methods of coal exploration and recovery. It also discusses uses of the coal produced in Colorado and new technology affecting the use of coal.

Physical Geology, by L. Don Leet and Sheldon Judson, Third Edition.

This geology textbook discusses the formation of coal, methods of finding coal and estimates of coal reserves.

Future Energy Alternatives for Colorado, by the Colorado Energy Research Institute, January 1976, Volume I, Volume II, and Summary Report.

This report examines production, reserves and demands for coal, oil, natural gas and other energy sources in Colorado. Alternative energy futures for the State are examined on the basis of projections of existing trends, on extensive use of conservation efforts, under maximum production, and in the case of sudden interruptions of supply.

COAL RESOURCE MAPS

Selected Energy Resources and Pipelines
Colorado Land Use Commission
January, 1974
Scale 1:500,000

This map shows shallow coal deposits derived from the publication by Charles N. Speltz, U.S. Bureau of Mines, 1976, entitled "Strippable Coal Resources of Colorado."

Coal Mines of Colorado - Jefferson County
Prepared by the Colorado School of Mines
Foundation, Inc., 1964
Scale 1" = 1 mile

Adams County Planning Department
Natural Resources Map
Sand, Gravel and Coal
HB 1041 Technical Identification
Shallow Coal - Source data from U.S. Bureau of Mines report on Strippable Coal Resources of Colorado, by Charles Speltz

Deep Coal - Source data U.S.G.S. Open file report #74-27 "A Preliminary Report On a Zone Containing Thick Lignite Beds,Denver Basin, Colorado" by Paul Soister.

Boulder County Planning Department
Mineral Resources Map
Scale 1:24,000

Maps for the following USGS quadrangles:
- Erie
- Lafayette
- Louisville

Coal Mines and Coal Fields of Colorado by David C. Jones, 1976
Colorado Geological Survey
Scale 1:500,000

Energy Resource Development Map of Colorado
Compiled by Keith Murray, 1976
Colorado Geological Survey
Scale 1:500,000

U.S. Department of the Interior, Bureau of Land Management
Minerals Owned by the Federal Government, November 1974
Scale 1 inch = 2 miles
Set of 4 maps - Denver
Prospect Valley
Littleton
Deer Trail

Arapahoe County Planning Department
Lignite Coal Deposits
Scale 1:24,000
Set of 4 maps - Source data U.S.G.S. Open-file Report #74-27
by Paul Soister, 1974

Mined Areas of Boulder - Weld Coalfield
Scale 1:24,000
Source data - U.S. Bureau of Mines report "Analysis of the
Boulder - Weld Coalfield, Colorado", by
Raymond Lowrie, 1966

Map Showing Mined Areas of the Boulder-Weld Coal Field, Colorado
U.S.G.S. Front Range Urban Corridor, Colorado
Environmental Geologic and Hydrologic Studies MF-513
by Roger B. Colton, U.S.G.S. and Raymond Lowrie,
U.S. Bureau of Mines, 1973
Scale 1 inch = 4000 feet

Coal Fields of Northeastern Colorado Including Location of Mines
(Published approximately 1939)
Colorado State Planning Commission
Scale 1 inch = 4 miles

Preliminary Map Showing Lignite Zone, Denver Basin, Colorado
by Paul E. Soister, U.S.G.S., 1974
Scale 1:250,000

Map of Colorado Showing Coal-Bearing Regions and Fields
by E. R. Landis, U.S.G.S., published in 1959
Scale 1" = 20 miles

Energy Resources Map of Colorado
by U.S. Geological Survey and Colorado Geological Survey, 1977
Scale 1:500,000

Map Showing the Approximate Configuration and Depth to the Top
of the Laramie-Fox Hills Aquifer, Denver Basin, Colorado
by John C. Romero, Colorado Division of Water Resources and Eugene
R. Hampton, U.S. Geological Survey, 1972
Front Range Urban Corridor, Colorado
Environmental Geologic and Hydrologic Studies
Map I-791
Scale 1:500,000

Environmental Geology of Boulder County, Colorado - Map Sheet #2
Coal Resource Map - Areas of Remaining Coal Reserves
Boulder County Land Use Department, 1976
Scale 1:36,000

Mineral Resources Map
Boulder County Planning Department 1976
Scale 1:24,000
Maps for the following USGS Quadrangles: Louisville
Erie
Lafayette

PERSONAL CONTACTS FOR COAL RESOURCES INFORMATION

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OIL AND GAS

Criteria for Specification

Known oil and gas fields, as mapped and identified by the U.S. Geological Survey (U.S.G.S.) and the Colorado Geological Survey (C.G.S.) have been designated as environmentally significant natural resource areas in the Denver Region.[1]

Basis for Criteria

Oil and gas are the remains of once living matter that has decayed and been reduced to a form in which carbon and hydrogen are the principal elements. These elements combine in a variety of ways to form molecules of substances called "hydrocarbons." Naturally occurring oil deposits contain many kinds of hydrocarbons mixed together. Deposits of gas vary in type depending upon the particular combination of hydrogen atoms and carbon atoms. For example, four hydrogen atoms combined with one carbon atom makes CH_4, or methane gas. The gas in most of Colorado's gas fields is composed mainly of methane.

Most oil and gas has developed from organic remains originally deposited in marine sedimentary rock. Sedimentary rock is rock that has formed from accumulations of particles such as sand, silt or clay which have been compacted and hardened to form rock. Three basic conditions are necessary for the development of a deposit of oil or gas:[2]

(1) Source beds where the hydrocarbons can form.

(2) A relatively porous and permeable reservoir bed into which they can migrate.

(3) A trap at some point in the reservoir bed where they can become imprisoned.

Oil and gas accumulations occur in porous beds of rock which are underlain and overlain by virtually impervious rocks. The location where one can find pools, fields or a reservoir of oil or gas depends upon the migration of these substances to reservoir rocks. The source beds for most oil and gas fields lie directly above or below the reservoir beds. The oil and gas generally migrate more readily laterally through the rocks rather than vertically because the sedimentary rocks are more permeable laterally than vertically.

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[1] Adams, Arpahoe, Boulder, Denver, and Jefferson Counties.

[2] Physical Geology, Third Edition, by L. Don Leet and Sheldon Judson.

The accumulation of oil and gas into reservoirs sometimes occurs where the rock strata are folded into a dome-like formation which is called an anticlinal trap (Figure 1A). In this case, the principle of gravity explains the location of the oil and gas. If oil, gas and water are trapped in a dome and capped and confined by an impermeable formation, the oil and gas will accumulate at the crest of the dome (Figure 1A). The oil and gas will rise to the top since they are lighter than water. The gas will be the uppermost since it is lighter than the oil.

Another structure where oil and gas deposits might be located is an area where the rock structure might quickly change from a permeable material such as sandstone to a relatively impermeable material, such as clay or shale. In this case, the oil and gas in association with water would be impeded in their upward migration when they came into contact with the layer of impermeable material. Such a configuration is called a stratigraphic trap (Figure 1B). Most of the oil and gas fields in the Denver Region are examples of stratigraphic trap fields.

Since deposits of oil and gas seem to develop only in thick deposits of marine sediments, prospectors for oil and gas limit their searching mainly to sedimentary rock formations. The main methods used to locate deposits of oil and gas are core drilling, seismic prospecting and gravity prospecting.[3] These prospecting methods will provide evidence on whether or not there is an underground geologic structure that is likely to trap deposits of oil and gas. These tests do not give positive evidence that a reservoir of oil and/or gas does actually exist in the identified geologic structure.

Oil (petroleum) and natural gas have been discovered in relatively large quantities in the prairies of eastern Colorado, and the plateaus of western Colorado. As indicated previously, these fossil fuels generally occur in porous sandstone and limestone sedimentary rock layers where they have been confined by finer-grained less permeable overlying rock materials in or near folds or faults in the earth's crust.

Oil was first discovered in the State of Colorado in 1862 near Canon City. This was the first producing oil well west of the Mississippi River. Almost 40 years after that first discovery, oil was produced in the Denver Region near the City of Boulder. Small amounts of oil have been produced from sandstones and shale of the Pierre Formation near

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[3] Ibid.

FIGURES 1A and 1B

POSSIBLE LOCATIONS OF OIL AND GAS IN ROCK FORMATIONS

FIGURE 1A

ANTICLINAL TRAP
OIL AND GAS TRAPPED IN A DOME

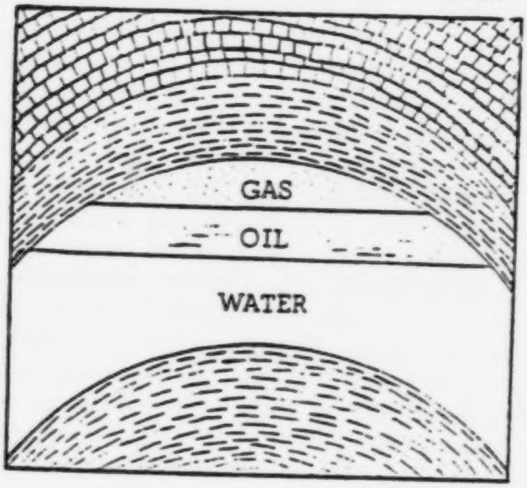
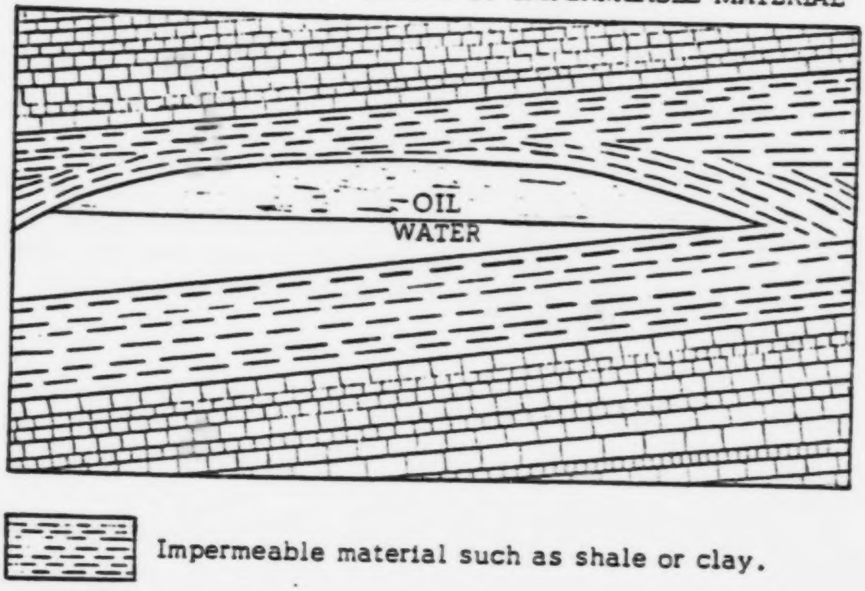


FIGURE 1B

STRATIGRAPHIC TRAP
OIL TRAPPED BETWEEN LAYERS OF IMPERMEABLE MATERIAL



▤ Impermeable material such as shale or clay.

▦ Permeable material such as limestone or other carbonate.

Boulder since 1900, and several old oil rigs can still be seen near the Boulder Reservoir. In this area the oil had been trapped in fractures of dense, impervious shale.

More recently, oil has been found in the "D" and "J" sands of the Dakota Sandstone in the Denver Basin. The Denver Basin is a spoon-shaped geologic basin structure that extends east/west from the plains near the small community of Deer Trail in eastern Arapahoe County, westward to the foothills, and north/south from the area around Greeley southward to slightly south of Colorado Springs. The oil in the Denver Basin has accumulated in lenses of sand which were deposited many millions of years ago in the Cretaceous period, when the area was covered by a sea. The oil and gas pools in the Dakota Sandstone throughout the main part of the Denver Basin are located in stratigraphic traps (Figure 1B) consisting of porous lenses of sandstone which extend out laterally into relatively impervious shale. In many cases, the general orientation of the oil and gas bearing sand lenses is northeast-southwest, which appears to be the same orientation of the shoreline of the ancient Cretaceous sea. More than 90% of the total oil produced in the Denver Basin has come from the Dakota Sandstone and about 99% of the gas produced in this region has come from the Dakota Sandstone.[4] Individual oil pools in the Denver Basin are generally small, but they are quite numerous.

In 1975 there were 550 producing oil and gas wells in the Denver Region. Of these wells, 419 were in Adams County, 128 were in Arapahoe County, and three were in Boulder County.[5] This number of producing wells represents a large increase over 1965, when there were 69 producing wells in the region with 68 located in Adams County, one in Boulder County, and none in Arapahoe County (Table 1).

Actual quantities of oil and gas produced in this region have also increased greatly over the past decade, especially from 1970 to the present. Oil production in the region increased from less than 600,000 barrels produced in 1965 to over 6,000,000 barrels produced in 1972.[6] Oil production since 1972 has decreased slightly to approximately 4,400,000 barrels produced in 1975. Adams and Arapahoe Counties are large oil producers in this region. Boulder County produces some oil, but amounts have been less than 2,500 barrels per year over the past decade. Figure 2 shows oil production in the region for Adams and Arpahoe Counties from 1965-1975.

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[4] Mineral and Water Resources of Colorado, U.S. Geological Survey.

[5] Oil and Gas Statistics - 1975, Colorado Oil and Gas Conservation Commission.

[6] Oil and Gas Statistics - 1965-1975, Colorado Oil and Gas Conservation Commision.

TABLE 1

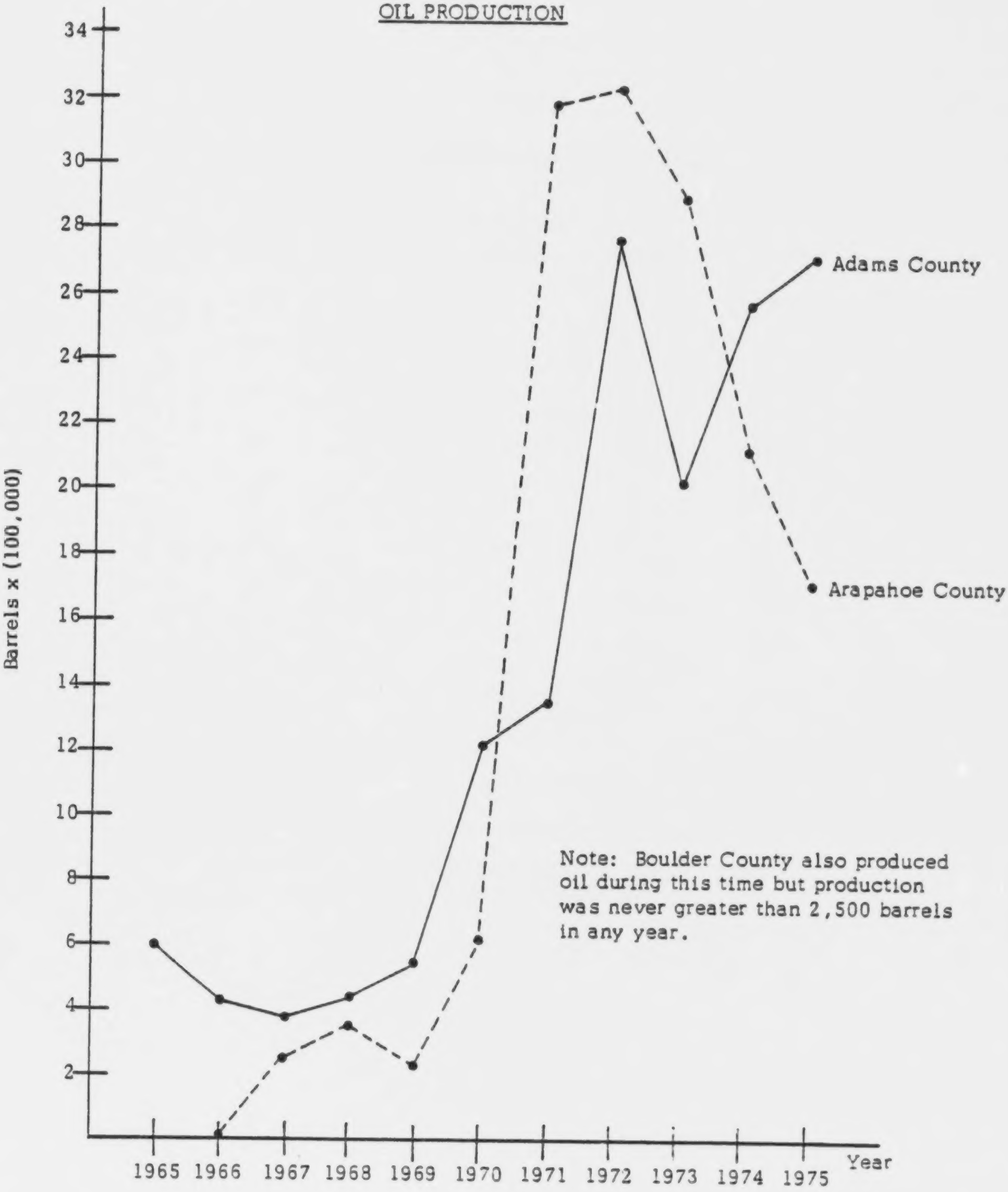
PRODUCING OIL AND GAS WELLS

Year	Adams County	Arapahoe County	Boulder County	Total Region
1965	68	0	1	69
1966	66	0	3	69
1967	69	7	3	79
1968	58	11	3	72
1969	63	11	0	74
1970	70	52	1	123
1971	103	91	1	195
1972	155	107	2	264
1973	216	115	2	333
1974	314	130	2	446
1975	419	128	3	550

Source: Oil and Gas Statistics 1965-1975, Colorado Oil and Gas Conservation Commission.

Figure 2

OIL PRODUCTION



Note: Boulder County also produced oil during this time but production was never greater than 2,500 barrels in any year.

Production of gas in the region has skyrocketed in the last decade with the most dramatic increase having occurred in Adams County. In 1965, Adams County was producing approximately two billion cubic feet of gas per year and by 1975 annual production had jumped to more than 24 billion cubic feet of gas. Gas production in the region increased from less than two billion cubic feet per year from 1965 through 1969, to an annual production of more than 29 billion cubic feet of gas in 1975.[7] Gas is produced in both Adams and Arapahoe Counties in the Denver Region, and production data by county from 1965 to 1975 is shown in Figure 3.

The value of both oil and gas production has also increased significantly within the past decade, and especially within the period from 1970 to 1975. This increase in value is not only a result of increased production of oil and gas but is also due to increases in the prices obtained for oil and gas. The value of oil production increased significantly in the region from 1969 to the present (Figure 4). The value of oil production for the region was less than three million dollars in 1969; at that time the value of oil production in Adams County was $1.7 million and the value of production in Arapahoe County was $.7 million. By 1975 the annual value of oil production for the Denver Region was greater than 42 million dollars of which $26 million of production was in Adams County, $16.5 million of production in Arapahoe County and about $16,000 in Boulder County.[8] Average prices for oil during this period increased from approximately $2.90 per barrel of oil in 1966, to $3.55 per barrel in 1972, then a great increase to $7.50 per barrel in 1973 and an average price of approximately $9.60 per barrel in 1975. Oil prices for early 1977 varied from $5.26 to $14.30 per barrel depending upon the age and quality of the oil.[9]

The value of production of gas in this region also increased significantly in the past decade, although that increase has been erratic in the last few years. In 1966, the annual value of production of natural gas in this region was less than $250,000, but by 1973, the value of gas production in this region had increased to over $9,000,000. In 1975 the value of gas production in this region had decreased to slightly less than $8,000,000 (Figure 4). Average prices for gas vary significantly from state to state, and even from county to county. In 1966, the average gas prices were about 13¢ per thousand cubic feet (Mcf) of natural gas. This figure rose slightly to about 17¢ per Mcf in 1972, and then soared to approximately 42¢ per Mcf in 1973. Trends in recent gas prices are

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[7] *Ibid*.

[8] *A Summary of Mineral Industry Activities in Colorado, 1975*, Colorado Division of Mines.

[9] 1977 price information from Oil Price Bulletins by Amoco Oil Corporation.

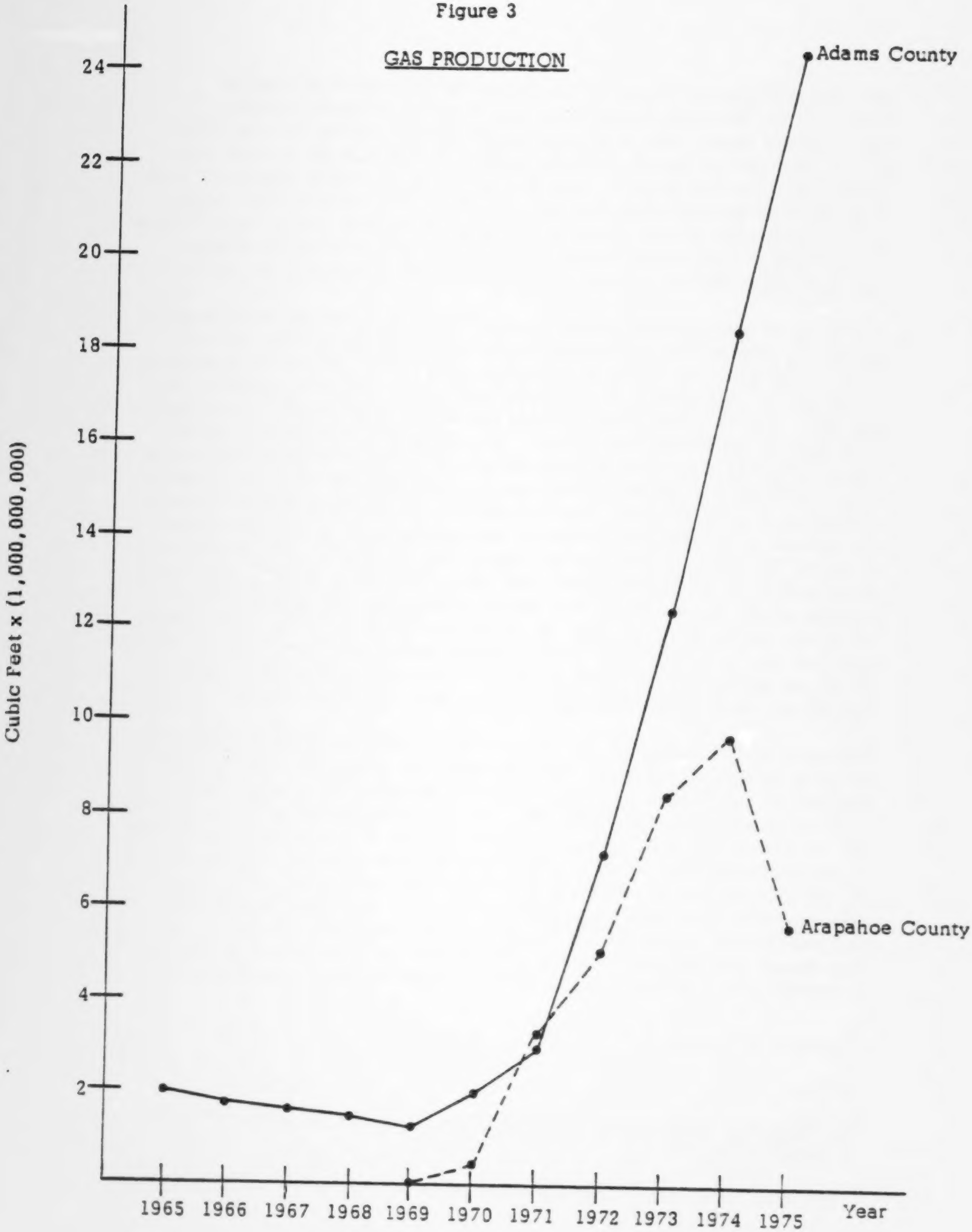
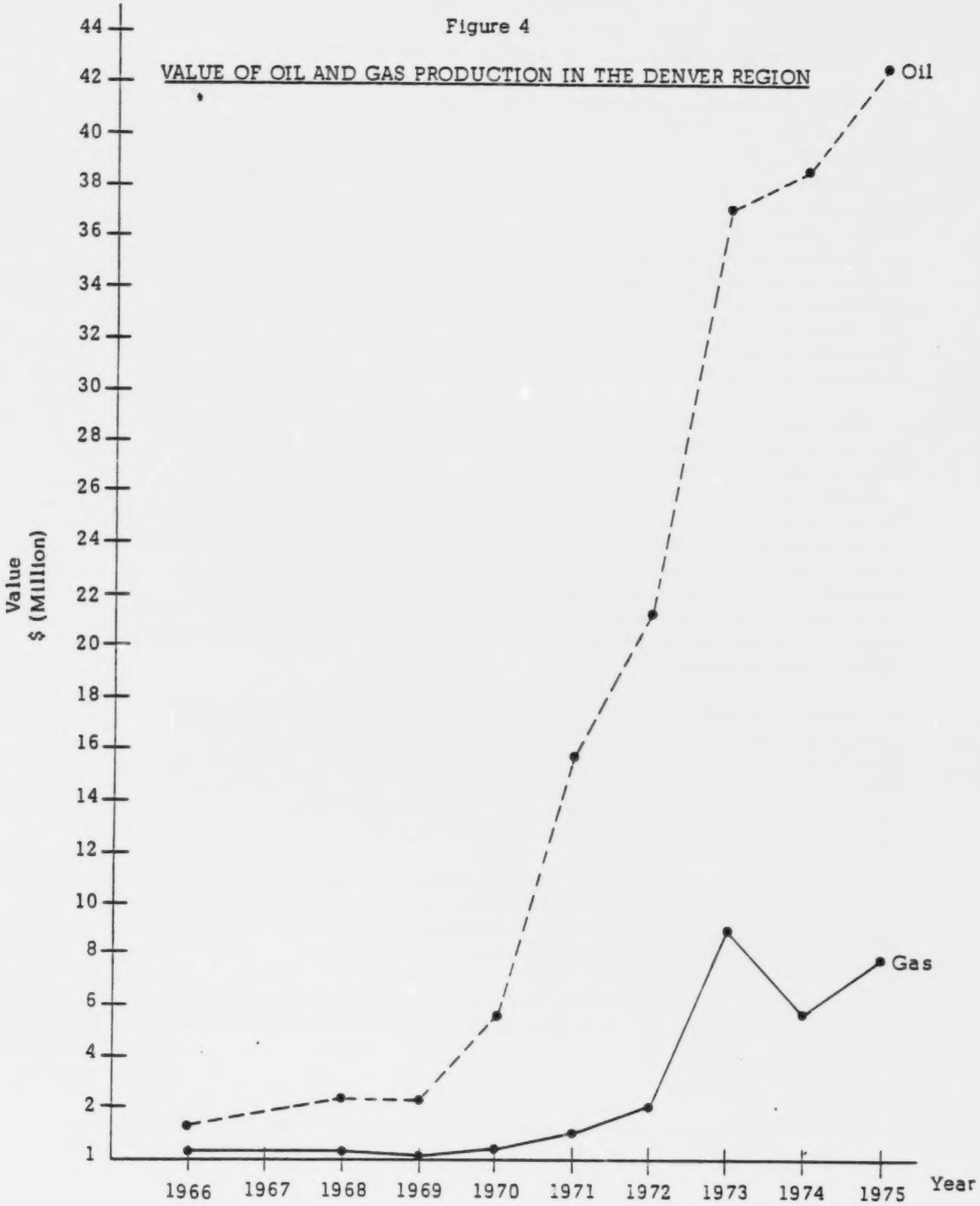


Figure 3

GAS PRODUCTION

Figure 4

VALUE OF OIL AND GAS PRODUCTION IN THE DENVER REGION



very unpredictable due to government price controls fixed by the Federal Power Commission (FPC). Gas prices can vary from 29.5¢ per Mcf to $1.44 per Mcf depending upon the vintage or age of the gas.[10]

The previously discussed production of oil and gas in this region all comes from known deposits of oil and gas. Those areas that were mapped by the U.S.G.S. and C.G.S. as oil and gas fields, and designated as environmentally significant natural resource areas in the Denver Region, are known deposits of oil and gas. In planning for the future use of vital energy resources such as oil and gas, it is important not only to study the existing known deposits, but to determine reserves of the resource. Neither the Colorado Geological Survey, nor the Colorado Oil and Gas Conservation Commission make estimates of reserves for individual oil and gas fields in the state. Reserve estimates for the entire state are published annually by the American Petroleum Institute (API) and the American Gas Association (AGA).

In 1976, the Colorado School of Mines Research Institute published oil and gas reserve estimates for the 25 largest oil and gas fields in the State of Colorado. Reserve estimates of oil and gas were also prepared and tabulated by producing formations in each of the basins in the state, by age of the producing formation, and by counties. The reserve estimates for the counties in the Denver Region are included in Table 2. An analysis of the estimated oil reserves in this region shows that the estimated reserves in both Adams and Arapahoe Counties are about equal to the total cumulative amount that has been produced thus far. In other words, about half of the estimated total known deposits of oil in this region have already been extracted.

Gas reserve estimates indicate that only about 16 percent of the total estimated supply of gas in this region has been extracted. Most of the estimated reserves of gas are located in Adams County. Approximately 596,403,356 thousand cubic feet of estimated gas reserves exist in this region, of which 466,532,524 thousand cubic feet or 78 percent of the total estimated reserve is located in Adams County.

Oil and gas are environmentally significant natural resources because of their use as fossil fuels. In addition to the obvious uses of oil and gas for transportation and heating, oil and gas are basic materials necessary for making plastics and many chemicals.

Natural gas is light, clean, and very efficient. In addition, use of natural gas produces the least amount of pollution when compared to all other fossil fuels.

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[10] Personal communication with George Tung, State Planning and Budgeting Office, April 1977.

TABLE 2

ESTIMATED OIL AND GAS RESERVES

By County - January 1, 1975

County	Cumulative Production	Estimated Reserves	Estimated Ultimate Production
OIL (Production in Barrels)			
Adams	22,398,386	22,297,912	44,696,298
Arapahoe	12,924,613	10,454,735	23,379,348
Boulder	777,001	10,000	787,001
Jefferson	15,275	0	15,275
Region Total	36,115,275	32,762,647	68,877,922
GAS (Production in Thousand Cubic Feet)			
Adams	67,445,448	466,532,524	533,977,972
Arapahoe	27,463,425	35,048,139	62,511,564
Jefferson	3,820	0	3,820
Region Total	94,912,693	501,580,663	596,493,356

Source: Oil and Gas Reserves of Colorado, Colorado School of Mines Mineral Industries Bulletin Volume 19, Number 5, September, 1976 by John D. Haun, A. Lynn Cardwell, Wilson H. Herrod, and James M. Cronoble.

Crude oil production in Colorado is the number one mineral product of the state in terms of value of production. In 1975, the value of production from crude oil accounted for 45 percent of the total value of all mineral production including metallic minerals, non-metallic minerals and mineral fuels.

Total consumption of gas in the State of Colorado has increased 63% from 1966 to 1974. This amount of increase is 2.3 times the rate of population increase in Colorado. Presently only 40% of the total amount of gas consumed in Colorado is domestically produced. About 50% of the oil used in Colorado is domestically produced.[11] Much of the oil produced in the region is sent through pipelines eastward and out of the state.

Thus far, the State of Colorado as a whole has already extracted 80 percent of the total estimated amounts of oil deposits in the state. This means that the remaining reserves represent only about 20 percent of the total estimated oil resources in the State. Cumulative production of gas in the State has been about 50 percent of the estimated ultimate production.

Oil and gas are the most utilized of all mineral fuels and energy sources (including coal, uranium, etc.). On a nationwide basis, oil and gas account for 75 percent of all energy consumption, whereas remaining supplies of oil and gas only account for 10 percent of energy reserves.[12] Demand for and use of oil and gas has increased significantly in the past five years. However, during this period domestic production of oil has decreased by six percent and foreign imports of oil have doubled.[13]

Because of the importance of this resource for use as fuel energy, and because of the diminishing amounts of oil and gas reserves at the regional, state, and national level, it is important that oil and gas exploration efforts be increased. With technological advancements producing better methods of locating and extracting oil and gas, these intensified exploration efforts should help locate additional sources of both continental and offshore oil resources to help supply this nation's increasing energy demands.

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[11] Future Energy Alternatives for Colorado, by the Colorado Energy Research Institute, January 1976.

[12] Statistics stated by President Jimmy Carter in his Energy Plan Address to Congress and the Nation on April 20, 1977.

[13] Ibid.

MAPPING STUDIES USED IN DESIGNATING OIL AND GAS IN THE DENVER REGION

Energy Resources Map of Colorado
by U.S. Geological Survey and Colorado Geological Survey, 1977
compiled by D. A. Myers and J. A. Sharps, U.S. Geological Survey and D. K. Murray, D. C. Jones, and R. H. Pearl, Colorado Geological Survey
U.S. Geological Survey Map I-1039

Scale 1:500,000

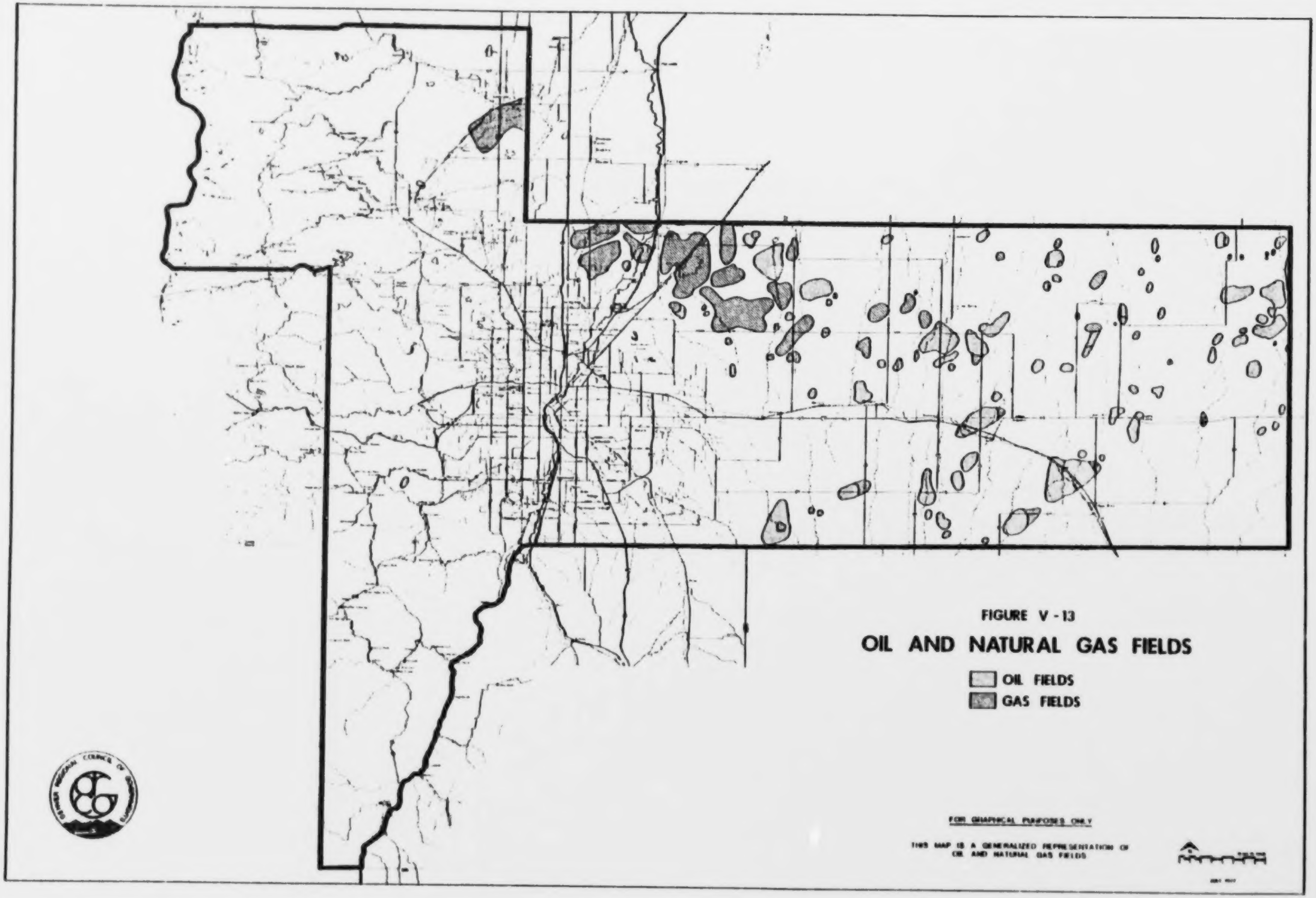

FIGURE V - 13

OIL AND NATURAL GAS FIELDS

☐ OIL FIELDS
▨ GAS FIELDS

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF
OIL AND NATURAL GAS FIELDS

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Oil and Gas Reserves of Colorado , Colorado School of Mines Mineral Industries Bulletin, Volume 19, Number 5, September, 1976, by John D. Haun, A. Lynn Cardwell, Wilson H. Herrod, and James M. Cronoble.

This report sets forth reserve estimates for the 25 largest oil and gas fields in the state of Colorado. Reserve estimates are also made for oil and gas by basin, by age of the producing formation, and by county.

Prairie, Peak and Plateau - A Guide to the Geology of Colorado, by John and Halka Chronic, 1972, Colorado Geological Survey Bulletin 32.

This book is a non-technical, layman's version of the geology of the state of Colorado and its relationship to man and his uses of the land.

"Selected Energy Resources and Pipelines, Colorado, 1974", published by the Colorado Land Use Commission, January, 1974.

This map includes a brief description of oil and gas production in the state, as well as showing locations of oil and natural gas fields.

"Oil and Gas Fields of Colorado - Statistical Data", Information Series 3 compiled by David C. Jones and D. Keith Murray, Colorado Geological Survey, 1976.

This publication includes statistical data on all currently producing and abandoned oil and gas fields on record in the Colorado Oil and Gas Conservation Commission through 1974. Data compiled on each field includes location, number of producing wells, geologic age, and cumulative production.

Mineral and Water Resources of Colorado, Report of the United States Geological Survey in Collaboration with the Colorado Mining and Industrial Development Board, 1964.

This report discusses production and reserves of oil and gas in Colorado and describes the location and characteristics of oil and gas fields in different regions of the State.

Future Energy Alternatives for Colorado, by the Colorado Energy Research Institute, January 1976, Volume I, Volume II, and Summary Report.

This report examines production, reserves and demands for coal, oil, natural gas and other energy sources in Colorado. Alternative energy futures for the State are examined on the basis of projections of existing trends, on extensive use of conservation efforts, under maximum production and in the case of sudden interruptions of supply.

"World Energy Outlook" Exxon Background Series, April 1977.

This report investigates factors critical to world energy supply and demand. Energy resources which are evaluated are coal, oil, gas, nuclear power, and hydroelectric power.

1975 Oil and Gas Statistics, Colorado Oil and Gas Conservation Commission, Department of Natural Resources.

This publication is an annual report of oil and gas production by each producing field in the state. Information is also included on drilling, injection projects, and gas storage projects.

1973 Oil and Gas Statistics, Colorado Oil and Gas Conservation Commission.

1971 Oil and Gas Statistics, Colorado Oil and Gas Conservation Commission.

A Summary of Mineral Industry Activities in Colorado, 1975, published by the Colorado Division of Mines.

This publication is an annual report of the value of production of metals, non-metallic minerals and mineral fuels in the state of Colorado. This data is also presented by individual counties. Also included in this report is information on annual mining employment and mining injuries.

A Summary of Mineral Industry Activities in Colorado, 1974, Colorado Division of Mines.

A Summary of Mineral Industry Activities in Colorado, 1973, Colorado Division of Mines.

A Summary of Mineral Industry Activities in Colorado, 1972, Colorado Division of Mines.

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This publication includes data on mineral production and value of mineral production by county. Data on principal oil and gas discoveries in the past year are also compiled by location of the field and county.

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This geology textbook discusses the chemical characteristics of oil and gas, the geological formations where oil and gas are likely to be found, and methods of finding oil and gas.

Earth and Man, by Frank Byrne, 1974.

This textbook on geology and other earth sciences includes a discussion on use and production of oil and natural gas throughout the world.

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1972 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1970 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1969 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1968 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1967 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1966 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

1965 Oil and Gas Statistics, published by the Colorado Oil and Gas Conservation Commission.

Colorado Energy Resources Handbook - Volume 2: Oil Shale, prepared by J. G. Morse, Colorado Energy Research Institute, published by Colorado School of Mines, October 1976.

This report includes data on oil shale resources in Colorado and potential impacts associated with the development of an oil shale industry in the state.

OIL AND GAS MAPS

Energy Resources Map of Colorado, by U.S. Geological Survey and Colorado Geological Survey, 1977, compiled by D. A. Myers and J. A. Sharps, U.S. Geological Survey, and D. K. Murray, D. C. Jones, and R. H. Pearl, Colorado Geological Survey, U.S.G.S. Map I-1039
Scale 1:500,000

Energy Resource Development Map of Colorado, compiled by D. Keith Murray, Colorado Geological Survey, 1976, Map Series 6. Prepared in cooperation with the Governor's Energy Policy Council and the Colorado Energy Research Institute.
Scale 1:500,000

Selected Energy Resources and Pipelines, Colorado, 1974, published by the Colorado Land Use Commission, January, 1974.
Scale 1:500,000

Oil and Gas Resources
Arapahoe County Planning Department
Set of four maps
Scale 1:24,000

Oil and Natural Gas
HB-1041 Technical Identification Map
Adams County Planning Department
Set of two maps
Scale 1:48,000

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AQUIFERS

Criteria for Specification

An aquifer is an underground geologic rock unit which contains permeable material that stores, transmits, and dispenses groundwater. In the Denver Region there are two types of aquifers --- alluvial aquifers and bedrock aquifers.

The alluvial aquifers are composed of unconsolidated valley-fill alluvium along the South Platte River and its tributaries. The bedrock aquifers are composed of semi-consolidated to consolidated sandstones in a large geologic structural depression known as the Denver Basin. The major bedrock aquifers in the Denver Basin are the Laramie-Fox Hills aquifer and the aquifers of the Dawson Group. These bedrock aquifers underly the Denver Region[1] from the hogbacks along the foothills on the western boundary to the gently westward dipping outcrop on the eastern boundary. This eastern boundary is on the plains slightly east of the small community of Deer Trail in Arapahoe County. In these outcrop areas of the Fox Hills and Laramie sandstones along the Denver Basin's east and west borders, precipitation seeps directly into the aquifer thus recharging its supply of groundwater. The outcrop areas of probable bedrock aquifer recharge and the alluvial aquifers of the South Platte River and its tributaries are designated as environmentally significant areas in the Denver Region.

Basis for Criteria

An aquifer is defined as an underground geological formation, group of formations or part of a formation which contains sufficient saturated permeable material that can store, transmit and yield a sufficient quantity of water that may be extracted and applied to beneficial use. An aquifer may occur in consolidated bedrock such as limestone, basalt, or sandstone or it may occur in unconsolidated alluvial materials such as gravels or sands. Both bedrock and alluvial aquifers occur in the Denver Region.

The principal bedrock aquifers are part of the geologic structure known as the Denver Basin. The Denver Basin is a spoon-shaped basin which is generally defined in geological terms by the exposure of the Fox

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

Hills Formation. It basically extends west to the foothills, south to Colorado Springs, north toward Greeley and eastward toward the general area of Deer Trail in Arapahoe County (Figure 1). The main bedrock aquifers in the Denver Basin are the Laramie-Fox Hills aquifer and the aquifers of the Dawson Group. These will be discussed in detail further on in this report.

The alluvial aquifers occur in unconsolidated materials such as sand and gravel, which are found as deposits in river and stream valleys. Alluvial aquifers generally have a higher storage capacity and more stable water levels than the bedrock aquifers because they have more void space between the particles of the unconsolidated materials and because they are recharged by precipitation, surface runoff, and occasionally by groundwater discharge from fractures in the underlying and adjacent bedrock material. Alluvial aquifers generally have a greater amplitude in seasonal fluctuation due to local recharge and discharge; however, the long-term storage capacity trend usually is quite stable and shows little change. Bedrock aquifers, on the other hand, show less effect from local immediate recharge and discharge but they show a greater response to long-term continuous pumping.

An aquifer stores, dispenses and transmits water. The amount of water which it can hold and the rate at which it can yield and transmit groundwater depend upon the porosity and the permeability of the material of which the aquifer is composed. Porosity is the percentage of open space in the rock or earth material composing the aquifer. Porosity is a necessary component of permeability, which is the ability of a material to transmit fluids. However, highly porous materials are not necessarily highly permeable. In order to be permeable, the material in the formation must not only contain many open spaces between the particles that compose that material, but those spaces must also be interconnected and large enough to overcome the molecular attraction between water molecules and the molecules of the material in the formation.

The water which is stored undergound in aquifers is released and transmitted to the surface through man-made wells or natural discharge such as springs or by natural seepage into wetlands, ponds, lakes, rivers, and streams. Water is also replenished to the aquifers from the ground surface. Water from rivers, lakes, and wetlands can seep down into the aquifer and replenish it, and where the bedrock formation of the aquifer outcrops, precipitation and runoff can percolate directly into the aquifer. Irrigation water also replenishes and recharges aquifers. Thusly, aquifers moderate surface flow of water; they absorb water during rains or periods of high flow and they release water (either naturally or by well withdrawal) during periods of low flow.

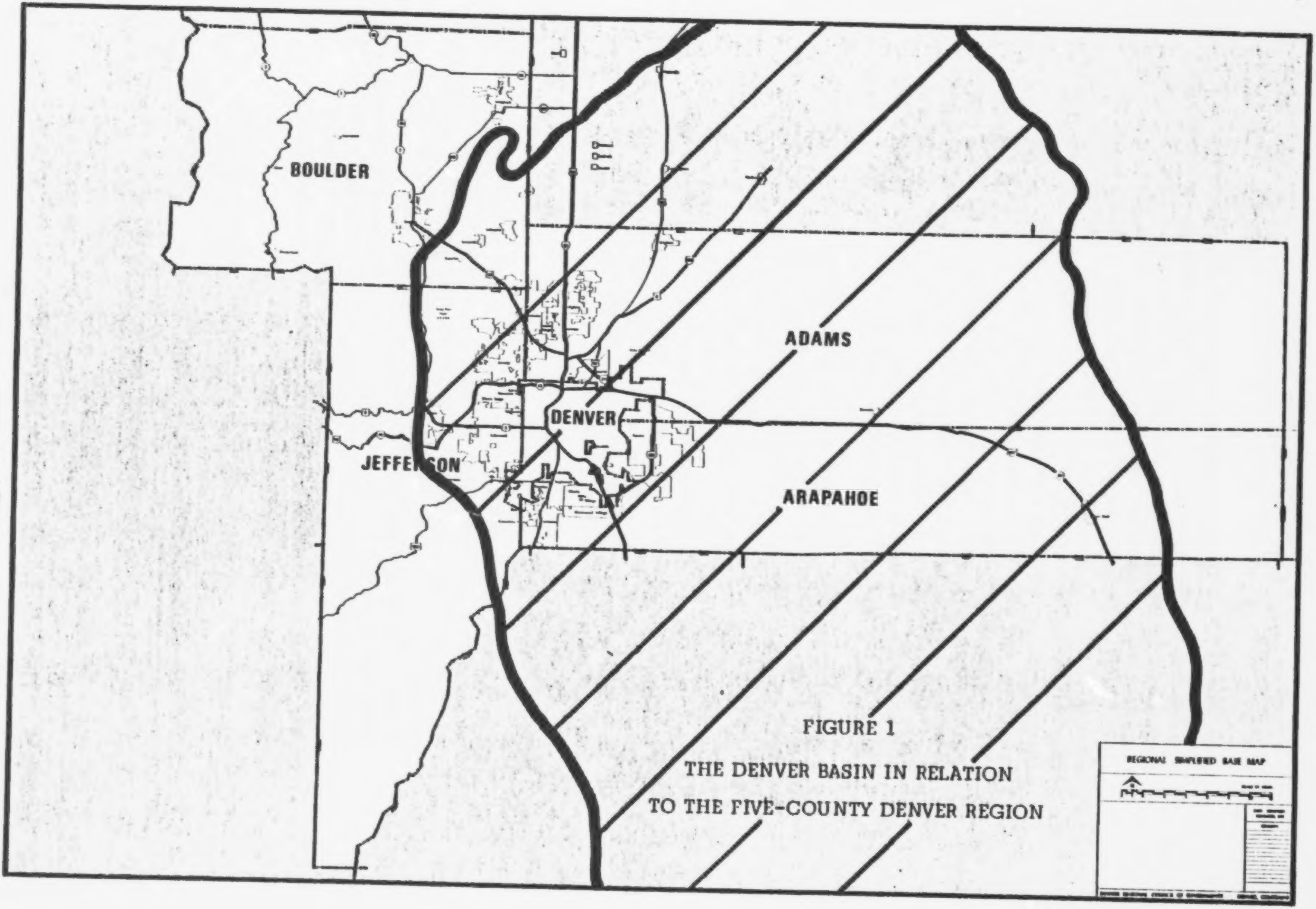
BOULDER
ADAMS
DENVER
JEFFERSON
ARAPAHOE
REGIONAL SIMPLIFIED BASE MAP

FIGURE 1

THE DENVER BASIN IN RELATION TO THE FIVE-COUNTY DENVER REGION

Natural limitations to the amount of water which may be extracted from a given aquifer do exist. Although many aquifers are replenished or recharged by seepage from adjacent water bearing formations, all aquifers depend, somehow, upon the infiltration of surface water either through seepage from surface water bodies such as lakes or streams or from the percolation of precipitation for recharging of the groundwater supply. The amount of water which enters the aquifer each year through rainfall percolation or surface water seepage, determines the amount of water that can be withdrawn annually without seriously depleting the aquifer; this quantity is frequently referred to as safe yield. Withdrawals exceeding this supply must come from storage within the aquifer. All withdrawals will deplete an aquifer to a greater or lesser extent. The volume of withdrawal will be divided between aquifer depletion and either induced seepage and leakage or reduced ground water outflow.

Several factors determine the amount of aquifer recharge each year. The amount, duration, and intensity of precipitation are the major factors, and other contributing factors are the amount of applied irrigation water, topography, permeability of the soil and rock materials, and the type and amounts of vegetation on slopes which reduces the velocity of rainfall runoff which helps more rain percolate into the ground. In the Denver region, the snowmelt from the Rocky Mountains supplies water to mountain streams. These streams then help supply water to the aquifer through seepage where the aquifers come in contact with the streams and by recharge from irrigation water diverted from the stream.

Alluvial Aquifers

In the Denver Region, the alluvial aquifers occur in valley-fill alluvium deposited in a channel which has been eroded into the underlying bedrock. This alluvium contains the unconfined aquifer which is in hydraulic connection with the South Platte River and its tributaries. These alluvial aquifers have been mapped by the U.S. Geological Survey.[2] Unconsolidated surficial deposits which compose the alluvial aquifers are the Piney Creek series of Alluvium, the Broadway Alluvium, portions of the Louviers Alluvium and some older terrace deposits. These surficial deposits are composed of sand, gravel and silty clay.

The sands and gravels which compose the alluvial aquifer have been accumulating for hundreds and thousands of years, and are more than 60 feet thick in some areas along the South Platte River.

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[2] Preliminary Map of Ground-Water Storage in the Alluvial Aquifers of the South Platte River Basin, Northeastern Colorado by R. Theodore Hurr, U.S Geological Survey, 1977

The depth to water in these valley-fill deposits ranges from 0 to about 80 feet.[3] Along First Creek on the site of Rocky Mountain Arsenal the alluvial deposits are as thick as 80 feet in some places.

The alluvial aquifers are recharged by precipitation, applied irrigation water, leakages from canals and reservoirs and groundwater inflow from other areas. Forty to fifty percent of the water that is applied to land for irrigation recharges, that is, returns to the groundwater in the alluvial aquifers. Alluvial aquifers, excluding eolian deposits occupy about 25-30 percent of the South Platte River drainage basin. The alluvial deposits are shallower and closer to the ground surface than the bedrock aquifers except in areas where the bedrock aquifers outcrop. Consequently, alluvial aquifers intercept most precipitation before it reaches the bedrock aquifers. The only areas it doesn't really intercept the rainwater first is the areas where the bedrock formation outcrops. An unknown quantity of water locally, then percolates past the alluvial aquifers and recharges underlying bedrock aquifers when the latter are in such a physical condition that such recharge can be accepted.

Bedrock Aquifers

In the Denver basin, there are several bedrock formations which meet the definition of an aquifer. In ascending temporal order from the Precambrian basement rocks, principal aquifers are the Fountain/ Formation, the Lyons Formation, the upper and lower parts of the Dakota Group, the Laramie-Fox Hills aquifer (the combined thickness of the Milliken Sandstone Member of the Fox Hills Formation and the A & B sandstones of the Laramie Formation), the middle part of the Laramie Formation, the Arapahoe Formation, Denver Formation, and Dawson Arkose (Figure 2). These rock formations are all consolidated to semiconsolidated sedimentary rocks. These aquifers and their characteristics have been studied and mapped by the Colorado Division of Water Resources.[4]

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[3] Ground-Water Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties, Colorado, Geological Survey Water-Supply Paper 1658, by Rex O. Smith, Paul A. Schneider, Jr., and Lester R. Petri, 1964

[4] Ground Water Resources of the Bedrock Aquifers of the Denver Basin Colorado, by John C. Romero, Division of Water Resources, Colorado Department of Natural Resources, 1976.

FIGURE 2

RELATIONSHIPS OF GEOLOGIC FORMATIONS WHICH COMPRISE THE BEDROCK AQUIFERS OF THE DENVER BASIN

Geologic Age Years Ago*	Geologic Unit	
Quaternary	Quaternary (recent) Surficial Deposits	
30 Tertiary	Castle Rock Conglomerate	
	Tertiary Intrusive and Extrusive Rocks	
	Dawson Group	Dawson Arkose
65		Denver Formation
		Arapahoe Formation
Upper Cretaceous	Laramie Formation	Upper part
		B sandstone
		A sandstone
	Fox Hills Sandstone	Milliken Sandstone
		Lower Part
	Pierre Formation	
	Niobrara Formation	Smoky Hill Shale
		Fort Hayes Limestone
	Benton Formation	Carlile Shale
		Greenhorn Limestone
		Graneros Shale
Lower Cretaceous	Dakota Group	South Platte Formation
		Lytle Formation
135 Jurassic	Morrison Formation	
	Ralston Creek Formation	
180 Triassic 225 Permian	Lykins Formation	Strain Shale
		Glennon Limestone
		Bergen Shale
		Falcon Limestone
		Harriman Shale
	Lyons Sandstone	
270 Pennsylvanian	Fountain Formation	

*Million years before present

Source: Modified from "Generalized Composite Section of the Geologic Units of the Denver Basin, Colorado" in Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

The rock formations which are classified as principal aquifers are assigned varying degrees of importance or significance depending on areal extent, depths to the water-bearing horizons, and quality and quantity of water available for withdrawal. Those aquifers which are classified as major aquifers are the Laramie-Fox Hills aquifer, and the aquifers in the Arapahoe Formation, Denver Formation, and the Dawson Arkose. Other water bearing sandstones in the Denver Region also function as aquifers in some areas, however, only the major bedrock aquifers in the region will be discussed in this report.

The sandstones of the Fox Hills Formation and the Laramie Formation yield small to moderate quantities of water to most wells in an area which covers approximately 5,000 square miles in the Denver Basin.[5] These sandstones are collectively referred to as the Laramie-Fox Hills aquifer. This aquifer is the oldest of the major aquifers in the Denver Basin and covers the largest area of the basin as it outcrops nearly all along the edge of the Denver Basin. The aquifer is composed of the basal part of the Laramie Formation and the top part of the underlying Fox Hills Formation. The Laramie-Fox Hills aquifer is classed as an artesian aquifer with the upper confining layer the upper part of the Laramie Formation and the lower confining bed the Pierre Formation.

The Laramie-Fox Hills aquifer is composed of a medium-grained sandstone 25-50 feet thick, overlying and grading downward into a layer 20-50 feet thick of finer-grained thin-bedded sandstone which is interbedded with siltstone and shale. All of these materials overly a layer of quartzose sandstone, siltstone and shale which is approximately 60 to 120 feet thick.[6] Younger materials including sandstone, shale and coal of the upper part of the Laramie Formation and sandstone and shale of the Dawson Group overly the materials which compose the Laramie-Fox Hills aquifer.

The thickness of the Laramie-Fox Hills aquifer ranges from 0 feet at its outcrops along the outside edge of the Denver Basin to about 400 feet thick with the average thickness about 200 feet. The depth to this aquifer ranges from 0 feet at its outcrops to about 2900 feet southeast of Castle Rock. In much of the central part of the Denver Basin the depth to the top of the aquifer is over 2000 feet, and consequently the demand for water, economics of well development, and alternative sources of water all must be carefully considered in making development decisions.

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[5] _Ibid_, Romero.

[6] Maps showing the Approximate Configuration and Depth to the Top of the Laramie-Fox Hills Aquifer, Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, and Eugene R. Hampton, U.S. Geological Survey, 1972.

Natural recharge to the Laramie-Fox Hills aquifer is by the infiltration of precipitation in areas of its outcrop and subcrop on both the east and west sides of the Basin, and probably through faults and rock joints along the foothills and in the area slightly northeast of Golden. Percolation of seepage from streams contributes to recharge along the foothills.

In addition, there is a definite possibility that the Laramie-Fox Hills aquifer is recharged indirectly by seepage of water through layers of clay and shale which overly the sandstone of the aquifer.[7] The source of this seepage may be precipitation or leakage from overlying aquifers. However, this indirect recharge is much slower than the direct recharge from seepage of precipitation in areas of outcrops of the Laramie and Fox Hills Formations.

Recharge also occurs as a result of pressure differentials created by large amounts of water withdrawal from wells. The movement of groundwater occurs from areas of greater to areas of lesser hydrostatic head,[8] with the prime moving force being gravity. When large amounts of water are pumped out, other water will move in to fill the void. This water comes from overlying and underlying formations or from more distant portions of the same aquifer formation from which the water was withdrawn. Such recharge is generally a relatively slow process.

As indicated previously, direct recharge to the Laramie-Fox Hills aquifer occurs in its areas of outcrop. In the Denver region, the Laramie-Fox Hills aquifer outcrops near the hogback ridges along the edge of the Front Range foothills along the western portion of the Denver Basin. These strata dip steeply eastward and underground toward the axis of the Denver Basin. Surface runoff and precipitation enters the porous sandstones of the Laramie-Fox Hills aquifer and percolates down to lower depths.

Direct recharge by infiltration of precipitation and stream seepage occurs only where the elevation of the hydrostatic head is below the elevation of the outcrop. The areas of outcrop of the Laramie-Fox Hills aquifer have been mapped by the Colorado Division of Water Resources and are designated as environmentally significant areas in the DRCOG Regional Growth and Development Plan.

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[7] Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

[8] Hydrostatic Head - a measure of pressure at a given point in a liquid in terms of the vertical height of a column of the liquid which would produce the same pressure.

In the northwest portion of the Basin near the foothills there are many faults. In these areas it is difficult to determine where the Laramie and Fox Hills Formations outcrop and receive direct recharge from precipitation. Studies have indicated, however, that there are many recharge areas along the upfaulted and exposed blocks of the Laramie-Fox Hills aquifer in this area. A study is currently underway by the Colorado Division of Water Resources and the U.S. Geological Survey to determine the recharge-discharge relationships in these faulted areas.

Taking into consideration all of the above mentioned ways of natural recharge, it has been estimated that the total quantity of natural recharge to the Laramie-Fox Hills aquifer is about 10,000 acre feet of water per year.[9]

Artificial recharge of water to the Laramie-Fox Hills aquifer might occur through seepage from water-diversion ditches; however, this amount of recharge is believed to be small when compared to amounts of recharge from other sources.

As indicated earlier, water moves into, through, and out of aquifers. Aquifer recharge is water moving into the aquifer and aquifer discharge is the process of water moving out. Water from the Laramie-Fox Hills aquifer is discharged naturally as seepage and springs in areas where the potentiometric surface[10] lies above the elevation of an outcrop. Calculations based upon hydraulic conductivity and slope of the potentiometric surface indicated that the total amount of water which is naturally discharged from the Laramie-Fox Hills aquifer ranges from about 5500 to 9400 acre feet of water per year.[11]

Water is artificially withdrawn from the Laramie-Fox Hills aquifer via a large number of domestic, commercial, industrial, stock, and municipal wells, many of which are located near the outcrop areas because of the shallower depths to the aquifer. Within the Denver

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[9] Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

[10] The potentiometric surface is a map of the hydrostatic head defined previously. It is an imaginary surface connecting levels to which water would rise in tightly cased wells from a given point in an aquifer. It represents the artesian pressure or hydraulic head throughout all or part of an artesian or confined aquifer.

[11] Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

Basin there were approximately 600 wells tapping into the Laramie-Fox Hills aquifer as of Winter 1974. Forty-six of these wells are municipal wells. The approximate annual withdrawal of water from the Laramie-Fox Hills aquifer from all the wells tapping into it is approximately 16,500 acre feet. Wells penetrating the Laramie-Fox Hills aquifer will generally yield between 50 and 100 gallons per minute.

Water from the Laramie-Fox Hills aquifer was first used in the metro Denver area in the late 1920's. In the 1940's and 1950's the demand upon this aquifer increased and consequently many new wells were drilled down into the sandstones of the Laramie-Fox Hills aquifer. Most of the use of water from this aquifer has occurred since the late 1940's, when many wells were drilled in the metropolitan Denver area for water supplies for suburban communities and water districts.

Water drawn from the Laramie-Fox Hills aquifer in the eastern portion of the Denver Basin is generally better than that drawn from this formation in the western portion of the Basin. In the western portion of the Basin the Laramie-Fox Hills aquifer water locally contains hydrogen sulfide and methane and occasionally has a high iron, chloride, and sulfate content.

The general term "Dawson Group" includes the Arapahoe Formation, the Denver Formation, and the Dawson Arkose, and each of these formations are considered major aquifers. The groundwater from the Dawson Group has been used more than all the other bedrock aquifers in the Denver Basin combined. This substantial use is due to two factors -- the quality of the water and the depths at which it is accessible. The quality of the water tapped from the aquifers in the Dawson Group is better than that from the Laramie-Fox Hills aquifer in that it is approximately 10° to 15° cooler, and because it does not possess excessive quantities of dissolved gases.[12] The groundwater from the aquifers in the Dawson Group can be tapped at depths ranging from 0 to 2500 feet depending upon location within the Denver Basin, and the quantity of the water demanded.

The deepest aquifer of the Dawson Group is the Arapahoe Formation (Figure 2). It is composed mainly of sandstone and conglomerate in the lower part and is approximately 500-600 feet thick. The Arapahoe Formation aquifer is a reliable source of groundwater which is of good to excellent quality. The depth to the Arapahoe Formation ranges from 0 feet in areas of outcrops to approximately 2500 feet in deep parts of the Denver Basin. The Arapahoe Formation is generally recharged in the same manner as the Laramie-Fox Hills aquifer. This recharge generally occurs along the formation outcrops which basically circumscribe the Denver Basin. The Arapahoe Formation generally discharges locally in the southern portion of the Basin south and east of the City of Colorado Springs and along the eastern edge of the basin near Limon, Colorado and near the northeast limits of the formation.

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[12] *Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado*, by John C. Romero, Colorado Division of Water Resources, 1976.

The aquifer of the Denver Formation lies above the Arapahoe Formation. It is composed of sandstones, conglomerates, claystones and shale. Data indicates that the reliable water-bearing strata are "aquifer zones" in the lower half of the Denver Formation. The "aquifer zones" are composed of a series of sandstones interbedded with shale and are frequently 100-150 feet thick. Not enough data has been collected on the Denver Formation to indicate which areas are recharge areas and which are discharge areas. However, it is logical to assume that recharge would occur in areas of outcrop and in areas where there are many wells creating a pressure differential from large amounts of water withdrawal.

The Dawson Arkose is also a reliable source of good quality groundwater. It is approximately 1100 feet thick and is composed of sandstone, conglomerates and shale. Existing data indicates that the principal water-bearing portions of this formation occur in the lower 400 to 500 feet of the formation and that the upper 500-600 feet of the formation includes water-bearing strata that is not as well developed as in the lower half.[13] Data is generally lacking on the aquifer characteristics of the Denver Formation and Dawson Arkose at this time, and consequently it cannot be analyzed as fully as the other major aquifers discussed in this report.

The aquifers of the Dawson Group are naturally recharged from the infiltration and percolation of precipitation in areas of outcrops and along fault zones along the foothills. Natural recharge may also occur as seepage from streams, rivers, and as percolation of precipitation through the overlying clay-shale strata. Water recharges readily into the coarse material of the Dawson Arkose. In many areas the Dawson Arkose is relatively close to the ground surface with only a few inches of overlying soil cover and consequently these areas are also good recharge areas.

Natural recharge to the Dawson Group is approximately 110,000 acre feet per year.[14] Some water is also artificially recharged to the Dawson Group. This water is in the form of waste-water from irrigation and domestic, stock, commerical, industrial and municipal systems. Not enough data is presently available to accurately estimate the amount of water recharged from these sources.

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[13] Ibid, Romero.

[14] Ibid, Romero.

Natural discharge of water from the Dawson Group occurs as springs and seepages. Some of the seepages of water out of the Dawson Arkose occur when rainwater enters the sand layers of the Dawson Arkose and then moves horizontally along the formation and seeps out at outcrops. It is estimated that the potential natural discharge from the Dawson Group is about 5200 acre-feet of water per year.

Water is artificially withdrawn from the Dawson Group by about 6000 wells in the Denver Basin (as of Winter 1974). Approximately 90% of these wells are domestic-stock wells. At that time (Winter 1974), there were about 130 municipal wells tapping the aquifers of the Dawson Group. This figure is approximately three times more than the number of municipal wells tapping the Laramie-Fox Hills aquifer. The approximate amount of total water withdrawn from all 6000 wells in the Dawson Group in the Denver Basin is estimated to be approximately 124,000 acre-feet per year.[15] The aquifers in the Dawson Group are artesian with the upper part of the Laramie Formation acting as the lower confining formation. Most of the high capacity wells in the Dawson Group go down into the Arapahoe Formation.

In the Denver region, water from wells into the Dawson Group has been used since 1883. By 1895, over 400 artesian wells into the Dawson Group were operating in the Denver metropolitan area. The depths of these wells generally ranged from about 100 to 800 feet deep. However, within 5 years (by 1900) many of these artesian wells stopped flowing naturally and pumps had to be installed. During the decades of the 1940's and 1950's, extensive development of the Dawson Arkose and Denver Formation as a source for many commercial, domestic, industrial and municipal water supplies occurred. With increasing development in this region there has been increased utilization of this aquifer for water supplies, and the pressure for increased development of this aquifer continues today along with pressures for increased urban development.

The economic suitability of use of water for most purposes depends upon the chemical characteristics of the water supply. The chemical composition of the water will determine which uses it is suitable for in its raw state and for which uses it must be treated in order to meet specific use requirements. Results from test data show that water from the Laramie-Fox Hills aquifer is occasionally more heavily mineralized than water from the other principal bedrock aquifers. This water is predominantly of fair to good quality for public and domestic use throughout most of the Denver Basin; however, in some localized places the water has high concentrations of fluoride, iron, sodium, hydrogen sulfide and methane. As mentioned earlier in this report, its temperature is warmer than water from the other aquifers in the Basin. In addition, methane and hydrogen sulfide have been detected in well water from the Laramie-Fox Hills aquifer in the northern Denver metropolitan area.[16]

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[15] _Ibid_. Romero

The problems of contamination of the goundwater are mainly in the northwest portion of the Denver Basin. The geology of the northwest portion of the Denver Basin is very complex, and is characterized by many faults which cut through the sedimentary formations and possibly extend down into the basement complex. In these areas, contaminants may seep through the faults and joints directly down into the groundwater stored in the aquifers, thereby contaminating the groundwater in those areas.

It is important to note that water taken from the Laramie-Fox Hills aquifer in other portions of the region frequently is of a quality comparable to water from the Arapahoe Formation and that some small communities and many private users of this Laramie-Fox Hills water do not treat the water before use. Water from the Laramie-Fox Hills aquifer also meets most requirements for local industrial and agricultural purposes.

Water quality tests indicate that the chemical quality of water from the Dawson Arkose meets most recommended drinking water standards, as well as standards required for all industrial and agricultural purposes. The water from the Dawson Arkose was among the least mineralized of all the water types that were sampled and tested.

Water from the Denver Formation is fair quality for domestic and public use, especially in areas where the water-bearing strata of the Denver Formation are greater than 500 feet below the ground surface. In general, the water from the Denver Formation has a low to medium mineral content.

Generally, water from the Arapahoe Formation can be classified as predominantly soft, slightly mineralized water. Several municipalities use water from the Arapahoe Formation for public water supply and this water generally receives very little or no treatment besides chlorination for safety purposes.[17] Water from the Arapahoe Formation also meets most industrial water use standards of interest in the Denver Basin.

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[16] _Ibid_. Romero

Aquifers are environmentally significant for many reasons, the most important of which is their function of storing and transmitting groundwater which is used for drinking and irrigation. In addition, aquifers function as natural filters for the groundwater that is used for consumption and related purposes. As the precipitation percolates through overlying soil and formations and through the water-bearing formation, it is filtered. The effectiveness of this filtering depends on the permeability of the aquifer. Highly permeable aquifers do little filtering, whereas less permeable aquifers are more effective filters.

Aquifers are also an important part of the hydrologic cycle. They are interconnected with lakes, rivers and wetlands, and consequently factors which affect water on the surface will affect the groundwater in the aquifer and vice versa. If recharge to the aquifer is reduced due to development over recharge areas (outcrops of the formations which function as aquifers), then amounts of available groundwater will be reduced. Construction of any impervious surface in aquifer recharge areas physically seals off the recharge area from percolation of precipitation, thereby decreasing recharge of the aquifer as well as increasing surface runoff. In addition, stream flow which is augmented by discharge of groundwater to the stream will also be reduced.

Aquifers are also environmentally sensitive areas because the quality of the water which they store and transmit can become seriously degraded through natural phenomena and through man's activities. In the Denver Region, the most visible and serious threat to the quality of groundwater stored in aquifers is through contamination by wastes from septic system leach fields. In areas characterized by a thin layer of soil over the bedrock, or in areas with faults and joints in the bedrock, the effluent from the leach fields is not totally ameliorated before it reaches the underlying groundwater. The groundwater is then contaminated by fecal coliform in the waste. This contaminated groundwater is often drawn up by nearby wells to be used for human consumption. This problem is more prevalent in the mountainous part of the region and it constitutes a very serious health problem.

A recent study by the U.S. Geological Survey and the Colorado Geological Survey on the quality of groundwater revealed that in the mountainous part of Jefferson County groundwater is continuously being recycled from septic system leach fields to wells often with inadequate treatment. This study also found that in some cases of poor well construction or inadequate well casing, or other geologic factors such as the existence of faults, some leachate flows directly into wells.[18]

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[17] Ibid. Romero.

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In addition to poorly planned and badly functioning waste disposal, such factors as urban runoff, heavy use of fertilizers and other land use practices can allow damaging substances such as dangerous bacteria or toxic chemicals to enter the groundwater. Areas where there is only a thin cover of soil or where the water table is very close to the ground surface are particularly susceptible to transmitting such contaminants into the groundwater stored in the aquifer.

Minerals contained in groundwater also affect its suitability for consumptive uses. Therefore, it is always important to have new potential supplies of groundwater sampled and analyzed for toxic trace minerals, radioactivity, and coliform bacteria.

Aquifers can also be environmental hazard areas in that excessive withdrawal of water from the aquifer may cause voids and compaction which results in ground subsidence. In some cases when water is withdrawn from the aquifer in excessive amounts, water from surrounding clay or silt layers will be drawn into the aquifer. The surrounding clay shrinks as the water is removed and as the clay dries out, thus reducing the clay's volume and causing subsidence.

Withdrawal of large quantities of water from the bedrock aquifers in the metropolitan Denver area has resulted in large declines in the potentiometric surface of these aquifers. The Laramie-Fox Hills aquifer and the aquifers of the Dawson Group have both experienced declines of height of the potentiometric surface from about 100 to 600 feet since they were first utilized from about 1900 on.[19] The greatest declines have occurred in the northern and southern portions of metropolitan Denver.

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[18] Geologic Control of Supply and Quality of Water in the Mountainous Part of Jefferson County, Colorado, by Warren H. Hofstra and Dennis C. Hall, 1975, Colorado Geological Survey Bulletin 36.

[19] Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

Areas in the Denver Basin in which current water level declines are large enough and rapid enough to be of particular concern are along the South Platte River Corridor between Denver and Greeley, the Strasburg-Byers-Deer Trail area, and parts of metropolitan Denver.

The rate of decline of the water level in certain parts of the Denver region has been tempered somewhat in recent years by replacing groundwater withdrawals by alternative sources of water supply, principally by diversions of water from the west slope of the Rockies. However, these diversions have not lessened the demand on the water source of the bedrock aquifers in all parts of the Denver region. As of 1975, five municipalities and forty-one water supply agencies in the five county Denver Region relied soley upon water from wells in aquifers for their entire water supply. At that same time, there were seven municipalities and eight water supply agencies that used well water to supplement surface water supplies.[20] Only ten municipalities and nine water supply agencies in this region use surface water entirely for their water supplies. Appendix A includes a listing of water supply agencies in the Denver Region along with the sources of water supply used by each of these agencies.

Even though the level of the potentiometric surface has declined over a large portion of the metropolitan area, the aquifers have not yet lost their capabilities of supplying relatively large amounts of water to wells. However, it must be emphasized that when additional use of these aquifers does occur, it must be with much study and caution.

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[20] Metropolitan Water Requirements and Resources 1975-2010, prepared by the Denver Water Department for the Colorado State Legislature

APPENDIX A

WATER SUPPLY SOURCES IN THE DENVER REGION

	Water Supply	
	Surface Water	Well Water
MAJOR SUPPLIERS		
Arvada	X	X
Aurora	X	X
Boulder	X	
Brighton		X
Broomfield	X	
Consolidated Mutual Water Co.	X	
Crestview Water and Sanitation District	X	X
Denver	X	
Englewood	X	X
Erie	X	X
Glendale		X
Golden	X	
Lafayette	X	
Left Hand Water Supply Co.	X	
Longmont	X	
Longs Peak Water Association Inc.	X	
Louisville	X	
Morrison	X	
North Table Mountain Water and Sanitation District	X	
South Adams County Water and Sanitation District	X	X
Thornton	X	X
Westminster	X	X
Willows Water District		X
SMALL, GROWING SUPPLIERS		
Special Districts		
Brownsville Water and Sanitation District		X
East Valley Water and Sanitation District		X

	Water Supply	
	Surface Water	Well Water
Special Districts (Cont'd)		
Hiland Acres Water and Sanitation District		X
Knollwood Water District		X
Olde Stage Water District		X
Pine Brook Water District		X
Private Organizations		
Eldorado Springs		X
High Plains Water Association		X
Mountain View Water Users Association		X
San Lazaro Water Association	X	
SMALL, FULLY DEVELOPED SUPPLIERS		
Brighton Mobile Home Park		X
Charlou Park Water Association		X
Eastlake Water and Sanitation District	X	X
Fairways Water and Sanitation District	X	
First Creek Improvement District		X
Grace Mar Water Association		X
Green Acres Mobile Home Park		X
Harvest Estates		X
Hazeltine Heights Water District		X
Hillcrest Villages Mobile Home Park		X
Hilltop Acres Water Association		X
Holly Mutual Water Company		X
Inspiration Valley Mobile Home Park		X
Larks Meadow Water Association		X
Maple Grove Water Association	X	X
North Washington Water Users Association		X
Orchard Hills Water District	X	X
Peak View Trailer Court		X
Shady Meadows Mobile Home Park		X
Shannon Water District		X
Sheridan Mobile Park		X
South Vale Water District		X
Spring Valley Water Association		X
Town and Country Mutual Water Co.		X
Trailer Haven		X
Westlake Water and Sanitation District		X

	Water Supply	
	Surface Water	Well Water
OTHER WATER SUPPLY AGENCIES WITHIN THE DENVER REGION, YET OUTSIDE OF THE PRIMARY METROPOLITAN AREA		
Adams County		
Bennett		X
Strasburg Sanitation and Water District		X
Arapahoe County		
Byers Water and Sanitation District		X
Deer Trail		X
Boulder County		
Big Springs Water and Sanitation District		X
Jamestown		X
Little Thompson Valley Water District	X	
Lyons	X	
Nederland	X	X
Silver Spruce Water Association		X
Ward	X	
Jefferson County		
Beaver Brook System	X	
Brook Forest Water District		X
Buffalo Park Association	X	X
Evergreen-Kittredge Water System	X	
Idledale Water and Sanitation District	X	X
Indian Hills Water District		X
Mount Vernon Country Club		X
Mountain Water and Sanitation District		X
Sphinx Park Water Company	X	X
Tiny Town Water District		X

Source: Metropolitan Water Requirements and Resources, 1975-2010, Volume II - Primary Study Area Appendix, Volume III - Secondary Study Area Appendix, prepared by the Denver Water Department for the Colorado State Legislature.

MAPPING STUDIES USED IN DESIGNATING AQUIFERS IN THE DENVER REGION

Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado
by John C. Romero, Division of Water Resources, Colorado Department of Natural Resources, 1976

Plate 1	Generalized Bedrock Geologic Map of the Denver Basin, Colorado Scale 1: 500,000
Plate 8	Generalized Potentiometric Surface and Recharge/ Discharge Area Map, Denver Basin, Colorado Scale 1: 500,000

Preliminary Map of Ground-Water Storage in the Alluvial Aquifers of the South Platte River Basin, Northeastern Colorado by R. Theodore Hurr, U.S. Geological Survey, 1977

Scale 1: 500,000

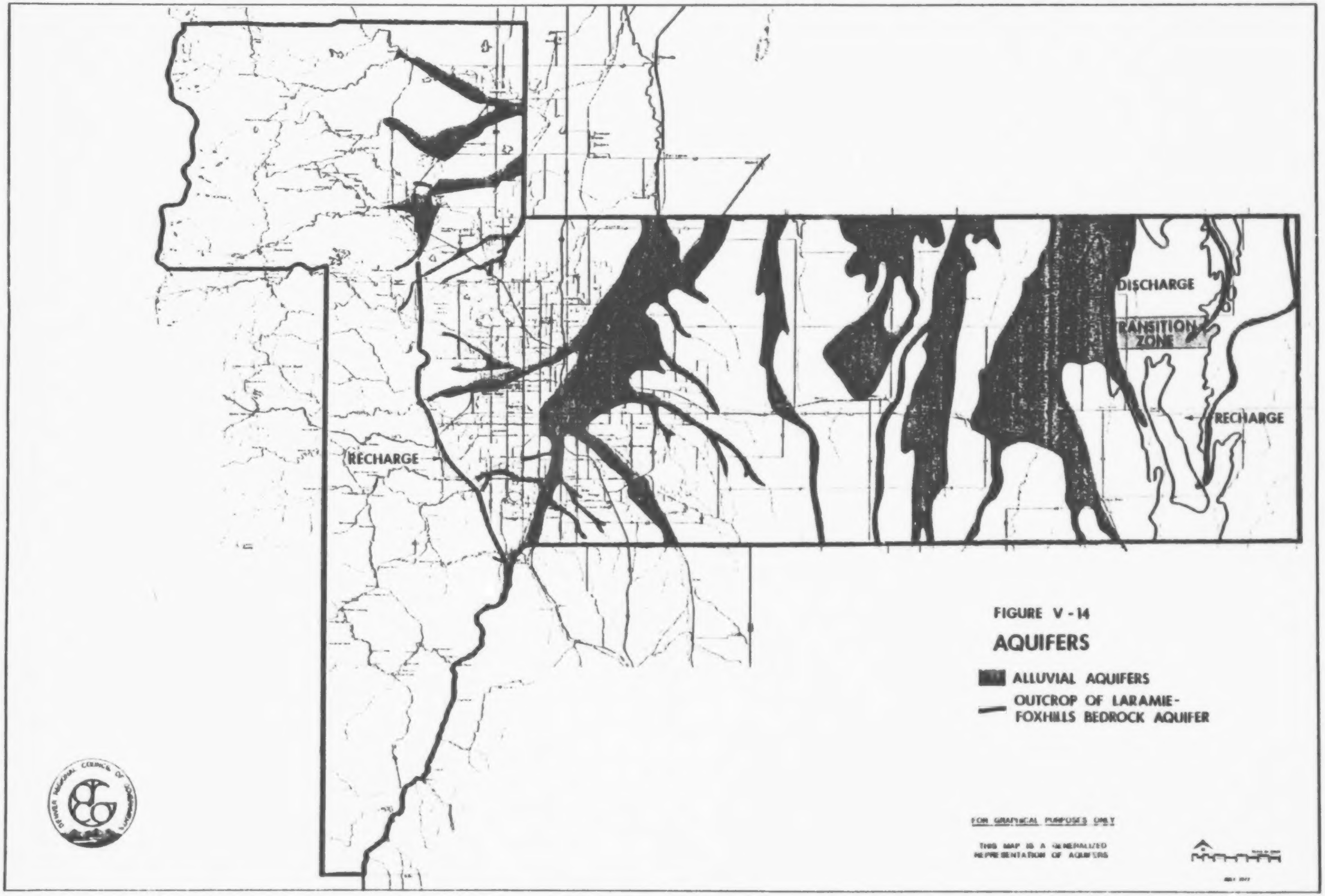
DISCHARGE
RANSITION ZONE
RECHARGE
RECHARGE
ALLUVIAL AQUIFERS
OUTCROP OF LARAMIE-FOXHILLS BEDROCK AQUIFER
FOR GRAPHICAL PURPOSES ONLY
THIS MAP IS A GENERALIZED REPRESENTATION OF AQUIFERS

FIGURE V-14

AQUIFERS

BIBLIOGRAPHY FOR AQUIFERS

Sources Available at DRCOG

AQUIFER REFERENCES

Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1976.

This study evaluates the hydrogeologic characteristics of each of the bedrock aquifers within the Denver Basin. It discusses the quantity, availability, chemical quality and use of the water from these aquifers. It also discusses natural recharge and natural and artificial discharge of water from the bedrock aquifers.

Map Showing the Approximate Configuration and Depth to the Top of the Laramie-Fox Hills Aquifer, Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, and Eugene R. Hampton, U.S. Geological Survey, 1972, Front Range Urban Corridor, Colorado Environmental Geologic and Hydrologic Studies.

This map includes a description which describes the basic characteristics of the Laramie-Fox Hills aquifer.

Ground-Water Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties, Colorado, Geological Survey Water-Supply Paper 1658, by Rex O. Smith, Paul A. Schneider, Jr., and Lester R. Petri, published in 1964.

This report includes an analysis of the character, thickness and extent of water-bearing formations associated with the South Platte River. It also studied the quantity, movement, availability and use of groundwater in the study area.

Hydrology of the South Platte River Valley, Northeastern Colorado, Colorado Water Resources Circular No. 28, by R. Theodore Hurr, Paul A. Schneider, Jr., and Donald R. Minges, U.S. Geological Survey, 1975.

This report describes the hydrologic and geologic aspects of the alluvial aquifers of the South Platte River Valley. It describes surface water flows, diversions, applications and methods of recharge.

Performance Controls for Sensitive Lands - A Practical Guide for Local Administrators, by Charles Thurow, William Toner and Duncan Erley. ASPO Planning Advisory Service Report Nos. 307, 308.

This report discusses aquifers in detail, emphasizing their functions as natural reservoirs for groundwater, and their functions of regulating stream flow. Methods of protecting aquifers are also discussed.

Geologic Control of Supply and Quality of Water in the Mountainous Part of Jefferson County, Colorado, by Warren E. Hofstra and Dennis C. Hall, 1975 Colorado Geological Survey Bulletin 36.

This study analyzes the quality of groundwater in the mountainous part of Jefferson County. Characteristics of groundwater that were studied were concentrations of dissolved solids, nitrate, chloride, potassium, phosphorous, and fecal coliform. Most of the water contamination problems resulted from seepage of effluent from septic system leach fields into the groundwater supplies.

Colorado Stratigraphic Correlation Chart, Colorado Geological Survey. Compiled by Richard Howard Pearl and D. Keith Murray, August, 1974.

Map Showing Availability of Hydrologic Data, Boulder - Fort Collins - Greeley Area, Front Range Urban Corridor, Colorado, by Eugene R. Hampton, Glen A. Clark, and Margaret H. McNutt, 1974, U.S. Geological Survey Map I-855-C.

This data source shows the locations of sites in the area which are monitored to obtain data on climate, surface water, and ground water. It also lists references on studies of hydrologic characteristics which have been completed for the study area.

"Bibliography of Hydrogeologic Reports in Colorado" Colorado Geological Survey Bulletin 33 by Richard Howard Pearl, 1971.

Metropolitan Water Requirements and Resources 1975-2010, Volume I - Text, Volume II - Primary Study Area Appendix, Volume III - Secondary Study Area Appendix, prepared by the Denver Water Department under the direction of Denver Regional Council of Governments for the Colorado State Legislature, 1975.

This report contains an inventory and analysis of existing water agencies in the Denver metropolitan area. It also examines requirements and alternatives for future service.

OTHER REFERENCES NOT AVAILABLE AT DRCOG

Physical Geology, by L. Don Leet and Sheldon Judson.

This geology textbook discusses underground water and its storage and movement in aquifers.

AQUIFER MAPS

Ground Water Resources of the Bedrock Aquifers of the Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, 1975. Includes the following maps (scale 1:500,000):

Plate	1	Bedrock geologic map of the Denver Basin
Plate	2	Surficial geologic map of the Denver Basin
Plate	3	Selected E-logs of deep wells in the Denver Basin
Plate	4	Structure contour map of the top of the L-F aquifer
Plate	5	Structure contour map of the base of the lowermost potential water sand in the L-F aquifer
Plate	6	Sandstone isolith map of the L-F aquifer
Plate	7	Isobath map of the top of the L-F aquifer
Plate	8	Map of the Denver Basin showing the approximate configuration of the L-F aquifer's potentiometric surface for 1970, the outcrop-subcrop areas, possible recharge and discharge areas, and approximate locations of wells known to tap the L-F aquifer
Plate	9	Structure contour map of the top of the Laramie Formation
Plate	10	Structure contour map of the top of the Arapahoe Formation
Plate	11	Structure contour map of the top of the Denver Formation
Plate	12	Map showing contours on the approximate density of registered discharges of wells tapping the Dawson Group of aquifers.

Map Showing the Approximate Configuration and Depth to the Top of the Laramie-Fox Hills Aquifer, Denver Basin, Colorado, by John C. Romero, Colorado Division of Water Resources, and Eugene R. Hampton, U.S. Geological Survey, 1972. Front Range Urban Corridor, Colorado, Environmental Geologic and Hydrologic Studies Map I-791, Scale 1:500,000.

Preliminary Map of Ground-Water Storage in the Alluvial Aquifers of the South Platte River Basin, Northeastern Colorado, by R. Theodore Hurr, U.S. Geological Survey, 1977, Scale 1:500,000.

Ground-Water Resources of the South Platte River Basin in Western Adams and Southwestern Weld Counties, Colorado, Geological Survey Water-Supply Paper 1658, by Rex O. Smith, Paul A. Schneider, Jr., and Lester R. Petri, 1964. Includes the following maps (scale 1" = 1 mile, 1:63,360):

Plate	1	Map of the South Platte River basin in western Adams and southwestern Weld Counties, Colorado, showing areal geology and location of geologic sections.

Plate 2 Geologic sections along lines A-A' through E-E'.
Plate 3 Geologic sections along lines F-F' through J-J'.
Plate 4 Map of the South Platte River basin showing configuration of the bedrock surface.
Plate 5 Map of the South Platte River basin showing contours on the water table in November 1957.
Plate 6 Map of the South Platte River basin showing depth to water in Western Adams and southwestern Weld Counties, Colorado, November 1957.
Plate 7 Map of the South Platte River basin showing location of wells for which records were collected.
Plate 8 Map of the South Platte River basin showing thickness of the saturated valley-fill deposits.
Plate 9 Map of the South Platte River basin showing chemical-quality sampling sites, network of irrigation canals, and contours on the land surface.
Plate 10 Ranges in specific conductance of water from the valley-fill deposits.

Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Brighton Reach of the South Platte River Valley, Colorado, by R. Theodore Hurr, and Paul A. Schneider, Jr., Water Resources Division, U.S. Geological Survey, 1972, Open File Report. Includes the following maps (scale 1" = 1 mile):

Plate 1 Location of wells in the Brighton reach of the South Platte River Valley, Colorado.
Plate 2 Map showing bedrock configuration beneath the valley-fill aquifer in the Brighton reach of the South Platte River Valley, Colorado.
Plate 3 Map showing water-table contours of the valley-fill aquifer in the Brighton reach of the South Platte River Valley, Colorado.
Plate 4 Map showing saturated thickness of the valley-fill aquifer in the Brighton reach of the South Platte River Valley, Colorado.
Plate 5 Map showing transmissivity of the valley-fill aquifer in the Brighton reach of the South Platte River Valley, Colorado.
Plate 6 Map showing stream-depletion-factor of the valley-fill aquifer in the Brighton reach of the South Platte River Valley, Colorado.

Hydrology of the South Platte River Valley, Northeastern Colorado, Colorado Water Resources Circular No. 28, by R. Theodore Hurr, Paul A. Schneider, Jr., and Donald R. Minges, U.S. Geological Survey, 1975. Includes the following maps (scale 1:500,000):

Plate 1 Surface-water flow and river gains and losses due to seepage and irrigation return flow, South Platte River in March and November, 1968. Gage height and altitude of median and mean annual floods and profiles of floods with recurrence intervals of 10, 25, and 50 years at gaging stations are also shown.

Plate 2 Bedrock configuration beneath the valley-fill aquifer and transmissivity of the valley-fill aquifer.

Plate 3 Saturated thickness of the valley-fill aquifer, geologic sections at selected locations, and configuration of the water-table surface, March, 1968.

Plate 4 Changes in ground-water levels in the valley-fill aquifer from autumn, 1947, to autumn, 1970, and hydrographs of water levels in selected wells, South Platte River Valley.

Plate 5 Dissolved-solids concentration of ground-water in the valley-fill aquifer based on analyses of samples collected by the U.S. Geological Survey in 1966, and the Federal Water Pollution Control Administration in 1965-66.

Hydrogeological Maps of the Alluvial Aquifer In and Adjacent to the Rocky Mountain Arsenal, Colorado, by Leonard F. Konikow, April, 1975, U.S. Geological Survey Open-File Report 74-342 (scale 1:48,000).

Map Showing Approximate Ground Water Conditions in the Parker Quadrangle, Arapahoe and Douglas Counties, Colorado, by John O. Maberry and Eugene R. Hampton, 1972, U.S. Geological Survey, Map I-770-K (scale 1:24,000).

Map Showing Availability of Hydrologic Data, Boulder - Fort Collins - Greeley Area, Front Range Urban Corridor, Colorado, by Eugene R. Hampton, Glen A. Clark, and Margaret H. McNutt, 1974, U.S. Geological Survey, Map I-855-C (scale 1:100,000).

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PRIME AGRICULTURAL SOILS

Criteria for Specification:

The general criteria for specification of prime agricultural soils in the Denver region[1] is based upon slope, soil capability classifications and predicted crop yields for both irrigated and non-irrigated cropland.

Criteria for Prime Irrigated Cropland

(1) Slope equal to or less than 5%, and

(2) U.S. Department of Agriculture Soil Conservation Service Soil Capability Class rating of I, II or III, and

(3) Predicted yield index of 17 tons of sugar beets per acre or greater.

Criteria for Dry Cropland of Regional Importance

(1) Slope equal to or less than 5%, and

(2) U.S. Department of Agriculture Soil Conservation Service Soil Capability Class rating of III or IV, and

(3) Predicted yield index of 13 bushels of winter wheat per acre or greater.

These criteria form a minimum basis for specification as prime agricultural soil. Soils must meet all of the above criteria in order to be classified as prime agricultural soil. This designation applies to all land in the Denver region except areas which are already developed and areas committed to forest, open space or park use.

Certain soil series that meet these basic conditions, however, are not delineated as prime agricultural soils because of specific internal soil qualities and characteristics that make that soil unsuitable for classification as "prime." Such qualities include the retention of salt buildups, a low moisture holding capacity, or other factors. The soils that were not designated as prime agricultural soils due to such limiting factors are listed in Appendix A along with the specific limitations of these soils.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

Basis for Criteria:

Much concern has been expressed in recent years about the conversion of hundreds of thousands of acres of land per year from agricultural use to urban use. The U.S. Department of Agriculture Soil Conservation Service (USDA SCS) has found that approximately 2 million acres of farmland are irreversibly lost to new urban development each year.

In addition, another 1 million acres per year from the period 1967 to 1976 were converted to lakes, ponds and reservoirs. Each acre taken from cropland by urban development often means that at least one more acre is "leapfrogged" or isolated by interspersed urban development and is thus also lost to farm production. Thus, in the past decade the nation has been adding land to urban and water uses at the rate of about 5 million acres a year,[2] with a corresponding loss to agriculture.

In the Denver region, data from the U.S. Bureau of Census shows that from 1969 to 1974 the amount of land in farms decreased by 154,288 acres or approximately 10%. From the period of 1964 to 1974, the region's land in farms decreased by a total of approximately 232,082 acres or 14% of the total amount of farmland. In Boulder County alone, 156,327 acres were converted to other used from 1964-1974. That figure represents a decrease in farmland of 57% over that decade. In Jefferson County, the conversion rates were almost as astounding. During that same 10 year period, 104,090 acres or 53% of the total acres of farmland were converted to other uses. These levels and rates of conversion have raised a concern regarding the loss of the agricultural land resource of the region, and to address this issue with knowledge, prime agricultural soils in the region must be identified.

Prime farmland as defined by the U.S. Department of Agriculture Soil Conservation Service is:

> "That land best suited for producing food, feed, forage, fiber and oilseed crops and is also available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land but not urban buildup land or water). It has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically when treated and managed, including water management, according to modern farming methods."

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[2] "Important Farmlands: A National View" by Raymond I. Dideriksen and R. Neil Sampson, USDA SCS in Journal of Soil and Water Conservation, Volume 31, Number 5, published by the Soil Conservation Society of America.

However, the soils which are classified as prime agricultural soils can vary depending upon the perspective from which one analyzes the soils. Consequently, there exists agricultural land which can be considered prime on a national basis, prime on a state basis, prime on a regional basis or prime on a local basis. The following discussion and the criteria for specification of prime agricultural soils, which were set forth on page one, are based upon this distinction and focuses on soil that is prime on a regional basis.

The Department of Agriculture and the Soil Conservation Service (SCS) are concerned about any action that will tend to impair the productive capacity of American agriculture. As a result of this concern, the SCS has established a program to make and keep a current inventory of the prime farmland and unique farmland of the nation. In order to carry out this policy, it was necessary for the SCS to set a specific definition and set of criteria for delineating prime agricultural land for the nation. The specific criteria used in this designation includes parameters for moisture supply, soil temperature regime, soil pH, depth to the water table, depth to which roots can penetrate, soil erodibility hazard, soil permeability rate, frequency of flooding on the soils and percentage of coarse rock fragments in the surface layer of the soils. Prime farmland soils must have an adequate and dependable moisture supply from natural rainfall or from irrigation. They must have a warm enough soil temperature and a long enough growing season for the crops that are adapted to the area. They must be neither too acidic nor too alkaline for healthy plant growth and they must be permeable to both air and water and not subject to frequent flooding. Prime soils must not be highly erosive or so stony that they interfere with cultivation by machinery.

The nation's prime agricultural and unique farmland inventory is presently in progress and certain counties have been mapped and inventoried at this time. In the Denver region the national inventory of prime farmland has been prepared for Boulder County and a similar inventory is in progress for Adams County. Inventories of prime agricultural lands were initiated by the USDA SCS in 122 counties in 1975. In addition to mapping prime farmland, unique farmlands (land particularly suited to production of a specific speciality crop), farmland of statewide importance and farmland of local importance were mapped on these county maps. The classification of lands for statewide and local importance varies significantly depending on the concern for cropland expressed at the state and local levels. The USDA plans to inventory and map important farmlands of 250 counties in 1977 and to prepare 300 county important farmland inventories a year from 1978 on until all 3,068 counties in the nation are inventoried.

It has been indicated that because of the low amounts of rainfall in Colorado the non-irrigated soil here will not meet the national criteria for classification as prime agricultural land. Some irrigated lands, however, would be classified as prime farmland on a national basis. The SCS for the State of Colorado has yet to prepare maps of soils which are of statewide importance and the local studies that do exist are scattered throughout the state.

One important factor in studying agricultural land and its productivity is its efficiency in terms of energy utilization. Such information would relate the amount of energy expenditures in terms of inputs of intensive management, fertilizer, petroleum fuels, and agricultural chemicals. Presently, no classification system exists that can rank land in terms of its capacity to achieve given levels of output with minimum inputs of energy. Lands have not yet been classified or graded based on their yield at low energy input levels. If there were such a system, it is thought that the dryland wheat producing land of eastern Colorado might be some of the most prime land or highest energy efficient land in the nation. However, according to the existing USDA SCS definition of prime farmland, this land wouldn't even be designated as prime on a nationwide basis because of the lack of rainfall.

The basic and most important information needed to specify prime agricultural lands is the soil information included in a soil survey. In the Denver region, soil surveys have been completed and published by the USDA SCS for Adams County, Arapahoe County and the part of Boulder County east of the Roosevelt National Forest. No soil survey was prepared by the USDA SCS for Denver County since it is an urban, non-agricultural county and the soil survey for Jefferson County is currently in progress. A soil survey contains a wide range of specific information about the soils in an area including soil slope and soil capability classification. These basic characteristics were analyzed to develop a preliminary list of prime agricultural soils in the region. A capability classification is the grouping of soils to show, in a general way, their suitability for most kinds of farming. It is basically a practical classification based upon the physical limitations of the soils, the risk of damage to the soils (mainly soil loss due to erosion) when they are used for farming, and the way the soils respond to treatment. In the SCS soil capability classification system, the soils are all grouped at three levels: the capability class, the subclass and the unit.

Capability classes are the broadest groups and are designated by Roman numerals I through VIII. The higher the numeral the greater the limitations of the soil and the narrower the choices for practical use. On a national basis, Class I soils have few limitations that restrict their use. Class II soils have moderate limitations that reduce the choice of plants which can be effectively grown or which require moderate conservation practices. Class III soils have severe limitations that reduce the choice of plants, require special conservation practices or both. Class IV soils have very severe limitations that restrict the choice of plants, require very careful management or both. Class V through Class VIII soils have more severe limitations which would exclude them from any consideration as prime farmland.

Capability subclasses are soil groups within one capability class. They are designated by a small letter "e," "w," "s," or "c" added to the capability class numeral (example IIs). Each of these small letters represents the major type of limitation to use of that soil. The letter "e" indicates that the main soil limitation is risk of erosion unless a close-growing plant cover is maintained. The letter "w" indicates that water in or on the soil interferes with plant growth or crop cultivation, however, in some soils the wetness can be partially corrected by artificial drainage. The small letter "s" indicates that the soil is limited mainly because it is shallow, salty, droughty, or stony. And lastly, the letter "c," which is only used in some parts of the United States, indicates that the chief limitation is a climate that is too cold or too dry.

Capability units are soil groups within the soil subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity and other responses to management. A capability unit closely approximates the actual soil mapping unit of individual soils. Capability units are generally designated by a number added to the class numeral and the subclass letter (example IIs-2). Production can vary on different capability classes of soil depending upon the management they receive. It may require high or intensive management to obtain large yields on certain Class III and IV lands. Different levels of management can provide varying yields on lands of the same capability class.

In the Denver region, a capability classification for irrigated use was given to those soils which were irrigated at the time the soil survey was made, or which had a good potential of being irrigated in the near future. Capability classifications for non-irrigated use were assigned to soil units which were non-irrigated at the time of the soil survey. Certain soils are assigned capability classifications for both irrigated and non-irrigated use. This was the case when a given soil series was irrigated in some areas and non-irrigated in other areas of the county for which the soil survey was being prepared.

In addition to analyzing soil slope and capability units, an assessment of predicted yield of certain crops was made. The yield figures for selected crops were obtained from predicted yield figures listed in the published U.S. Department of Agriculture Soil Conservation Service Soil Surveys. These yield figures represent the yield averages under soil management techniques at the time the soil survey was made. Some soil surveys in this region were prepared up to ten years ago. Soil management

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practices have improved with new and advanced technologies and consequently the potential yields from most of the soils in this region are undoubtedly higher now.

Since the DRCOG region has two distinct types of cropland (irrigated and non-irrigated), select crop predicted yields were analyzed for each one. The yield figures are basically used as an index to show which soils, under proper management, are generally capable of producing higher yields. The predicted yield of sugar beets was chosen to be an important production factor for irrigated lands. Although the amount of sugar beets presently grown in this region is not as great as it was years ago, the predicted yield of sugar beets is a most useful index. It has been determined that lands which are well suited for use in growing sugar beets would also be generally well suited for many truck farming crops. There are many large truck farms in the region and they may be of greater significance in the future.

The crop which best indicates the productivity of non-irrigated or dry cropland is winter wheat. Winter wheat is the most important crop for the Denver region in terms of acreage harvested, total production and dollar value of production.[3] Consequently, the predicted yield of winter wheat was used as a criteria for designating prime non-irrigated cropland in the region. In general, a yield of five bushels of wheat per acre will justify a harvest and a yield of 35-45 bushels of wheat per acre is considered the maximum. A yield index of greater than 13 bushels per acre is considered as a substantial average index yield for criteria for designating prime agricultural land in the Denver region.

In summary, the data and characteristics of soils that were closely studied in regard to classifying the soils as "prime" were the soils' slope, the predicted yield of sugar beets for irrigated soils, the predicted yield of winter wheat for non-irrigated soils, and the capability classification of the soil which includes consideration of such physical soil qualities as soil composition, soil texture, soil structure, the depth to bedrock, the depth to the water table, the depth to which roots can effectively penetrate, the porosity of the soil, the permeability of the soil, the soil pH (alkalinity or acidity level), the soil temperature, the erodability of the soil and its susceptibility to flooding.

Based upon the above listed criteria, a preliminary list was compiled of the soils which might be considered as prime agricultural soils for this region. This list was then evaluated by staff of the Colorado Office of the U.S. Department of Agriculture, Soil Conservation Service.[4] Certain soils were then eliminated from this preliminary list based upon the individual expertise of the State SCS Office in regard to the characteristics of the soils on this preliminary list. The revised list was then evaluated and reviewed by each of the SCS district offices in the region. The purpose of these reviews was to obtain input from each district conservationist based upon their own specific knowledge of the soils in each individual district.[5]

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[3] Technical Memorandum, "Agricultural Land Use in the Denver Region," by Gail Hill, Denver Regional Council of Governments, November, 1976.

The recommendations of each SCS district office were then reviewed with the State SCS Office and a final list of prime agricultural soils was developed for Adams, Arapahoe and Boulder Counties. Prime agricultural soils were specified for prime irrigated soils and prime non-irrigated soils. Boulder and Adams County have soils which are prime for irrigated use, soils which are prime for non-irrigated use and soils which are prime for both irrigated or non-irrigated use. Only 1.1% of the soils in Arapahoe County are irrigated and, thus, the Arapahoe County soil survey did not evaluate soils in that county for irrigated use. Consequently, Arapahoe County only has soils which are designated as prime for non-irrigated use. However, if those soils were to be irrigated, they would all be classified as prime irrigated cropland.

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[4] USDA SCS staff of the Colorado State Office involved in the prime agricultural soils evaluation were Robert Dansdill and Dale Holden.

[5] The SCS District Conservationists who were contacted for input are as follows:

Bill Colgate - Western Adams County
Brighton, CO

Chuck Malone - Eastern Adams and Arapahoe Counties
Byers, CO

Carrol Hamon - Boulder County
Longmont, CO

Lee Bentz - Jefferson County and western Arapahoe Counties
Golden, CO

In addition, Alan Amen, soil scientist for the SCS who has had considerable experience in mapping the soils in this region, was consulted for his input.

The lists of prime agricultural soils for Adams, Arapahoe and Boulder Counties are included in Tables 1-5. A published soil survey is not presently available for Jefferson County, however, a detailed soil survey is in progress at this time. In order to delineate prime agricultural soils for Jefferson County, field soil suveyors of the U.S. Department of Agriculture Soil Conservation Service prepared a semi-detailed map of the prime agricultural soils in the county. The soils which were mapped as prime were generally of a slope from 0-3% although a few areas with slopes up to 5% were included. These soils were all of capability Class II and III and generally received top level management. They were delineated as prime for both irrigated and non-irrigated use, however, their historical use has generally been that of irrigated cropland. The soils which were included in the semi-detailed mapping of prime agricultural soils in Jefferson County are listed in Table 6.

Appendix B includes tabulations of the approximate acreage and percent of the counties' total land area by soil type of the prime agricultural soils in each county. It is important to note that these figures refer to the acreage and percent of the total of each soil unit within the county. In specifying prime agricultural soils in this region, only areas not covered by urban development or parkland were considered. Consequently, the actual acreage designated as prime agricultural soil will be less than the totals shown in Appendix B.

It is important to emphasize that this report identifies prime agricultural soils for the entire Denver Region based on the best data and techniques that are presently available. As new and better techniques to identify prime agricultural soils are developed (especially techniques that include criteria to evaluate the efficiency of energy utilization and production related to energy inputs), this identification of prime agricultural soils should be evaluated and updated accordingly.

TABLE 1

PRIME AGRICULTURAL SOILS
IRRIGATED
ADAMS COUNTY

Name	% Slope	Soil Symbol	Irrigated Capability Unit	Predicted Index Yield/Acre*
Nunn loam	0-1	NlA	I-1	25
●Nunn loam	1-3	NlB	IIe-1	24
Nunn clay loam	0-1	NuA	IIs-1	24
●Nunn clay loam	1-3	NuB	IIe-1	23
Satanta loam	0-1	SnA	I-1	25
●Satanta loam	1-3	SnB	IIe-1	24
●Platner loam	0-3	PlB	IIe-1	24
●Weld loam	1-3	WmB	IIe-1	24
●Ascalon sandy loam	1-3	AsB	IIe-2	24
Vona sandy loam	0-1	VoA	IIs-2	21
●Platner loam	3-5	PlC	IIIe-1	18
Dacono loam	1-3	DaB	IIIe-2	22
●Ascalon sandy loam	3-5	AsC	IIIe-3	19
●Truckton sandy loam	1-3	TuB	IIIe-4	21
Truckton sandy loam	3-5	TuC	IIIe-3	
●Vona sandy loam	1-3	VoB	IIIe-4	21
Vona sandy loam	3-5	VoC	IIIe-3	
Dacono loam	0-1	DaA	IIIs-2	26
●Ascalon loamy sand	0-3	ArB	IIIe-5	20
Truckton loamy sand	0-3	T+B	IIIe-5	18
Vona loamy sand	0-3	VnB	IIIe-5	18
Loamy alluvial land, Moderately Wet	0-3	Lw	IIIw-1	24
●Ulm loam	3-5	UlC	IIIe-1	17

* Yield: Tons of Sugar Beets per acre.

● These soils are used for both irrigated and non-irrigated cropland in the county and are prime for both uses.

SOURCE: Soil Survey of Adams County, Colorado; U. S. Department of Agriculture, Soil Conservation Service

TABLE 2

PRIME AGRICULTURAL SOILS
NON-IRRIGATED
ADAMS COUNTY

Name	% Slope	Soil Symbol	Non-Irrigated Capability Unit	Predicted Index Yield/Acre*
●Nunn loam	1-3	NlB	IIIc-1	19
●Platner loam	0-3	PlB	IIIc-1	19
●Platner loam	3-5	PlC	IIIe-6	18
●Satanta loam	1-3	SnB	IIIc-1	19
●Weld loam	1-3	WmB	IIIc-1	19
●Ascalon sandy loam	1-3	AsB	IIIe-7	17
●Truckton sandy loam	1-3	TuB	IIIe-7	17
●Nunn clay loam	1-3	NuB	IIIs-3	19
Adena loam	0-3	AaB	IVe-3	18
Adena loam	3-5	AaC	IVe-4	17
Ulm loam	1-3	UlB	IVe-3	16
●Ulm loam	3-5	UlC	IVe-4	14
Renohill loam	1-3	ReB	IVe-3	15
Stoneham loam	0-3	S+B	IVe-3	16
Adena-Colby Association	3-5	AcC	IVe-4	13
Terry fine sandy loam	0-3	TeB	IVe-5	15
●Vona sandy loam	1-3	VoB	IVe-5	16
●Ascalon sandy loam	3-5	AsC	IVe-7	
Ascalon-Vona sandy loams	1-5	AvC	IVe-7	16
Ascalon-Platner Association	0-5	At	IVe-7	18
●Ascalon loamy sand	0-3	ArB	IVe-9	16
Ascalon loamy sand	3-5	ArC	IVe-7	18

* Yield: Bushels of Winter Wheat per acre.

● These soils are used for both irrigated and non-irrigated cropland in the county and are prime for both uses.

NOTE: If these prime non-irrigated soils were to be irrigated, they would all be classified prime irrigated cropland.

SOURCE: Soil Survey of Adams County, Colorado; U.S. Department of Agriculture, Soil Conservation Service.

TABLE 3

PRIME AGRICULTURAL SOILS
NON-IRRIGATED
ARAPAHOE COUNTY

Name	% Slope	Soil Symbol	Non-Irrigated Capability Unit	Predicted Index Yield/Acre*
Bresser loam, gravelly subsoil variant	1-3	B+B	IIIc-1	17
Fondis silt loam	1-3	FdB	IIIc-1	19
Fondis silt loam	3-5	FdC	IIIe-2	18
Fort Collins loam	0-3	FrB	IIIc-1	17
Nunn loam	0-3	NlB	IIIc-1	19
Nunn-Bresser-Ascalon complex	0-3	NrB	IIIc-1	18
Weld silt loam	0-3	WeB	IIIc-1	19
Weld silt loam	3-5	WeC	IIIe-2	18
Bijou sandy loam	0-3	BlB	IIIe-1	17
Bresser sandy loam, terrace	0-3	BsB	IIIe-1	18
Buick loam	3-5	BxC	IIIe-2	14
Fondis-Colby silt loam	3-5	FoC	IIIe-2	16
Adena-Colby silt loam	1-5	AdC	IVe-1	17
Baca loam	3-5	BcC	IVe-1	15
Bresser-Truckton sandy loam	3-5	BvC	IVe-3	16
Adena-Colby fine sandy loams	1-5	AcC	IVe-6	17
Weld fine sandy loam	1-5	WdC	IVe-6	19
Bresser loamy sand, terrace	0-3	BrB	IVe-7	14
Bijou sandy loam, wet	0-3	BmB	IVw-1	18
Edgewater loam	0-3	EdB	IVw-1	17

*Yield: Bushels of Winter Wheat per acre.

NOTE: If these prime non-irrigated soils were to be irrigated, they would all be classified as prime irrigated cropland.

SOURCE: Soil Survey of Arapahoe County, Colorado, U. S. Department of Agriculture, Soil Conservation Service

TABLE 4

PRIME AGRICULTURAL SOILS
IRRIGATED
BOULDER COUNTY

Name	% Slope	Soil Symbol	Irrigated Capability Unit	Predicted Index Yield/Acre*
•Manvel loam	1-3	Me	IIe-1	20
•Weld loam	0-1	WlA	IIe-1	25
•Weld loam	1-3	WlB	IIe-1	24
Ascalon sandy loam	0-1	AcA	I	24
•Ascalon sandy loam	1-3	AcB	IIe-2	24
Nunn sandy clay loam	0-1	NnA	I	25
Nunn sandy clay loam	1-3	NnB	IIe-2	24
•Colby silty clay loam	1-3	CoB	IIe-1	24
Nunn clay loam	0-1	NuA	IIs-1	24
•Nunn clay loam	1-3	NuB	IIe-1	23
Nunn-Kim complex	0-3	Nv	IIe-1	23
•Weld-Colby complex	0-3	WoB	IIe-1	22
•Ascalon-Otero complex	0-3	AoB	IIe-2	24
•Weld fine sandy loam	1-3	WeB	IIe-2	24
Colby silty clay loam, wet	0-3	CsB	IIw-1	21
McClave clay loam	0-1	Mm	IIw-1	21
Calkins sandy loam	0-1	CaA	IIw-2	21
Calkins sandy loam	1-3	CaB	IIw-2	21
Colby silty clay loam	3-5	CoC	IIIe-2	18
•Nunn clay loam	3-5	NuC	IIIe-2	18
•Weld-Colby complex	3-5	WoC	IIIe-2	18
•Manter sandy loam	0-1	MdA	IIIe-4	22
•Manter sandy loam	1-3	MdB	IIIe-4	22
•Ascalon sandy loam	3-5	AcC	IIIe-6	19
•Ascalon-Otero complex	3-5	AoC	IIIe-6	17
Loveland soils	0-1	Lv	IIIw-1	20
•Hargreave fine sandy loam	1-3	HaB	IIIe-9	19
•Valmont clay loam	1-3	VaB	IIIe-3	19
•Valmont clay loam	3-5	VaC	IIIe-2	
•Weld loamy sand	1-4	WdB	IIIe-5	

* Yield: Tons of Sugar Beets per acre.

• These soils are used for both irrigated and non-irrigated cropland in the county and are prime for both uses.

SOURCE: Soil Survey of Boulder County Area, Colorado, U. S. Department of Agriculture, Soil Conservation Service.

TABLE 5

PRIME AGRICULTURAL SOILS
NON-IRRIGATED
BOULDER COUNTY

Name	% Slope	Soil Symbol	Non-Irrigated Capability Unit	Predicted Index Yield/Acre*
•Weld loam	0-1	WlA	IIIc-1	
•Weld loam	1-3	WlB	IIIc-1	19
•Weld-Colby complex	0-3	WoB	IIIc-1	17
•Nunn clay loam	1-3	NuB	IIIs-1	19
•Nunn clay loam	3-5	NuC	IIIe-7	18
•Weld-Colby complex	3-5	WoC	IIIe-7	15
•Valmont clay loam	1-3	VaB	IIIs-1	19
•Valmont clay loam	3-5	VaC	IIIe-7	18
•Ascalon sandy loam	1-3	AcB	IIIe-8	19
•Ascalon-Otero complex	0-3	AoB	IIIe-8	18
•Hargreave fine sandy loam	1-3	HaB	IIIe-8	19
•Manter sandy loam	0-1	MdA	IIIe-8	
•Manter sandy loam	1-3	MdB	IIIe-8	19
•Weld fine sandy loam	1-3	WeB	IIIe-8	19
•Colby silty clay loam	1-3	CoB	IVe-4	15
•Manvel loam	1-3	Me	IVe-4	15
•Ascalon sandy loam	3-5	AcC	IVe-7	18
•Ascalon-Otero complex	3-5	AoC	IVe-7	17
•Weld loamy sand	1-4	WdB	IVe-9	18

* Yield: Bushels of Winter Wheat per acre.

• These soils are used for both irrigated and non-irrigated cropland in the county and are prime for both uses.

NOTE: If these prime non-irrigated soils were to be irrigated, they would all be classified as prime irrigated cropland.

SOURCE: Soil Survey of Boulder County Area, Colorado, U. S. Department of Agriculture, Soil Conservation Service

TABLE 6

PRIME AGRICULTURAL SOILS
IRRIGATED AND NON-IRRIGATED
JEFFERSON COUNTY

Soil Map Symbol	Name	% Slope	Capability Subclass Irrigated	Capability Subclass Non-Irrigated
A	Table Mountain sandy loam	0-2	IIe	IIIe
B	Nunn clay loam	0-2	IIe	IIIs
	Nunn clay loam	2-5	IIIe	IIIe
	Denver clay loam	0-2	IIe	IIIs
	Englewood clay loam	0-2	IIe	IIIs
C	Lavate sandy loam	0-3	IIe	IIIe
	Stapleton gravelly sandy loam	0-3	IIe	IIIe
	Rednunn gravelly clay loam	0-2	IIe	IIIs
	Ascalon sandy loam	0-3	IIe	IIIe
	Ascalon sandy loam	3-5	IIIe	-
	Critchell gravelly sandy loam	0-3	IIe	IIIe
D	Platner loam	0-3	IIe	IIIc
	Platner loam	3-5	IIIe	IIIe
	Nunn loam	0-3	IIe	IIIc
E	Nunn loam	0-2	IIe	IIIc
	Dacono loam	0-2	IIe	IIIc
	Fluvents, loamy	0-2	IIe	IIIc

NOTE: This information is from a Provisional General Soil Map prepared during preliminary field study. A detail soil survey is currently underway in Jefferson County with more detailed information made available as the survey progresses.

APPENDIX A

SOILS WHICH MEET THE BASIC CRITERIA FOR CLASSIFICATION AS PRIME AGRICULTURAL SOILS IN THE DENVER REGION, BUT WHICH HAVE NOT BEEN DESIGNATED AS SUCH BECAUSE OF SPECIAL LIMITATIONS

			Capability Unit		Predicted Index Yields		
Soil Name	% Slope	Soil Symbol	Irrigated	Non-Irrigated	Irrigated*	Non-Irrigated*	Main Soil Limitation
Adams County							
Heldt clay	0-3	HIB	IIIs-1	IVs-3	20	15	Salt buildup
Vona loamy sand	0-3	VnB		IVe-8		13	Low moisture holding capacity summer fallowing is impractical●
Truckton loamy sand	0-3	TtB		IVe-9		14	Low moisture holding capacity; summer fallowing is impractical●
Arapahoe County							
Colby silt loam	1-5	CoC		IVe-1		13	Shallow solum, no subsoil
Truckton loamy sand	1-5	TrC		IVe-5		14	Low moisture holding capacity
Heldt clay	0-3	HIB		IVs-1		15	Salt buildup
Weld-Deertrail silt loams	0-3	WrB		IVs-1		15	Sodium problem
Boulder County							
Heldt clay	0-3	HeB	IIIe-1	IVe-4	16	15	Salt buildup
Gaynor silty clay loam	1-3	GaB		IVe-4		15	Medium depth over shale bedrock
Renohill silty clay loam	1-3	RnB		IVe-4		15	Impure unit, includes Gaynor and Samsil soils

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●These soils are prime for irrigated use, but they are not prime or suitable for dryland use because of the above stated limitations.

*Predicted index yield for irrgiated land is tons of sugar beets per acre. Predicted index yield for non-irrigated land is bushels of winter wheat per acre.

APPENDIX B

APPROXIMATE ACREAGE AND PROPORTIONATE EXTENT OF PRIME AGRICULTURAL SOILS IN THE DENVER REGION BY COUNTY

Soil Name	% Slope	Acreage	Percent of Total County Acreage
Adams County			
Adena loam	0-3	18,600	2.4
Adena loam	3-5	2,400	.3
Adena-Colby Association	3-5	67,700	8.1
Ascalon loamy sand	0-3	700	.1
Ascalon loamy sand	3-5	1,100	.1
Ascalon sandy loam	1-3	43,300	5.4
Ascalon sandy loam	3-5	17,300	2.2
Ascalon-Platner Association	0-5	7,700	1.0
Ascalon-Vona sandy loams	1-5	30,900	4.0
Dacona loam	0-1	3,100	.4
Dacona loam	1-3	400	*
Loamy alluvial land, moderately wet	0-3	12,400	1.5
Nunn loam	0-1	3,500	.4
Nunn loam	1-3	12,200	1.6
Nunn clay loam	0-1	3,200	.4
Nunn clay loam	1-3	5,100	.6
Platner loam	0-3	39,800	5.0
Platner loam	3-5	17,100	2.1
Renohill loam	1-3	700	.1
Satanta loam	0-1	1,100	.1
Satanta loam	1-3	400	*
Stoneham loam	0-3	1,300	.2
Terry fine sandy loam	0-3	800	.1
Truckton loamy sand	0-3	10,500	1.2
Truckton sandy loam	1-3	14,000	1.6
Truckton sandy loam	3-5	2,800	.3
Ulm loam	1-3	3,900	.4
Ulm loam	3-5	11,400	1.4
Vona loamy sand	0-3	4,300	.5
Vona sandy loam	0-1	4,000	.5
Vona sandy loam	1-3	3,400	.4
Vona sandy loam	3-5	1,400	.2
Weld loam	1-3	103,500	13.0
Total		450,000	55.6

* Less than .05 percent.

Soil Name	% Slope	Acreage	Percent of Total County Acreage
Arapahoe County			
Adena-Colby fine sandy loams	1-5	1,780	0.3
Adena-Colby silt loams	1-5	30,750	5.9
Baca loam	3-5	920	.2
Bijou sandy loam	0-3	3,330	.6
Bijou sandy loam, wet	0-3	2,000	.4
Bresser loamy sand, terrace	0-3	490	.1
Bresser sandy loam, terrace	0-3	4,280	.8
Bresser loam, gravelly subsoil variant	1-3	914	.2
Bresser-Truckton sandy loams	3-5	31,350	6.0
Buick loam	3-5	7,020	1.4
Edgewater loam	0-3	1,202	.2
Fondis silt loam	1-3	21,393	4.1
Fondis silt loam	3-5	12,620	2.4
Fondis-Colby silt loams	3-5	9,450	1.8
Fort Collins loam	0-3	1,440	.3
Nunn loam	0-3	26,888	5.2
Nunn-Bresser-Ascalon complex	0-3	54,390	10.4
Weld fine sandy loam	1-5	760	.1
Weld silt loam	0-3	16,670	3.2
Weld silt loam	3-5	2,150	.4
Total		229,797	44.0
Boulder County			
Ascalon sandy loam	0-1	1,300	0.5
Ascalon sandy loam	1-3	11,000	4.5
Ascalon sandy loam	3-5	4,800	2.0
Ascalon-Otero complex	0-3	1,200	.5
Ascalon-Otero complex	3-5	2,600	1.0
Calkins sandy loam	0-1	1,600	.7
Calkins sandy loam	1-3	1,700	.7
Colby silty clay loam	1-3	4,300	1.8
Colby silty clay loam	3-5	2,200	.9
Colby silty clay loam, wet	0-3	600	.2
Hargreave fine sandy loam	1-3	1,100	.5
Loveland soils	0-1	4,500	1.9
Manter sandy loam	0-1	400	.2
Manter sandy loam	1-3	2,100	.9
Manvel loam	1-3	2,100	.9
McClave clay loam	0-1	2,300	1.0
Nunn sandy clay loam	0-1	1,700	.7

Soil Name	% Slope	Acreage	Percent of Total County Acreage
Nunn sandy clay loam	1-3	3,400	1.4
Nunn clay loam	0-1	6,800	2.8
Nunn clay loam	1-3	15,300	6.3
Nunn clay loam	3-5	5,300	2.2
Nunn-Kim complex	0-3	2,600	1.0
Valmont clay loam	1-3	5,200	2.1
Valmont clay loam	3-5	1,200	.5
Weld loamy sand	1-4	220	.1
Weld fine sandy loam	1-3	1,400	.6
Weld loam	0-1	500	.2
Weld loam	1-3	3,400	1.4
Weld-Colby complex	0-3	1,900	.8
Weld-Colby complex	3-5	500	.2
Total		93,220	38.5
Jefferson County			
(Soil Group)			
Table Mountain Sandy loam	0-2	60	.01
Nunn clay loam	0-2	4,500**	.9
Nunn clay loam	2-5		
Denver clay loam	0-2		
Englewood clay loam	0-2		
Lavate sandy loam	0-3	500**	.1
Stapleton gravelly sandy loam	0-3		
Rednunn gravelly clay loam	0-2		
Ascalon sandy loam	0-3		
Ascalon sandy loam	3-5		
Critchell gravelly sandy loam	0-3		
Platner loam	0-3	800**	.2
Platner loam	3-5		
Nunn loam	0-3		
Nunn loam	0-2	50**	.01
Dacono loam	0-2		
Fluvents, loamy	0-2		

** Acreage figure for all soils within this soil group.

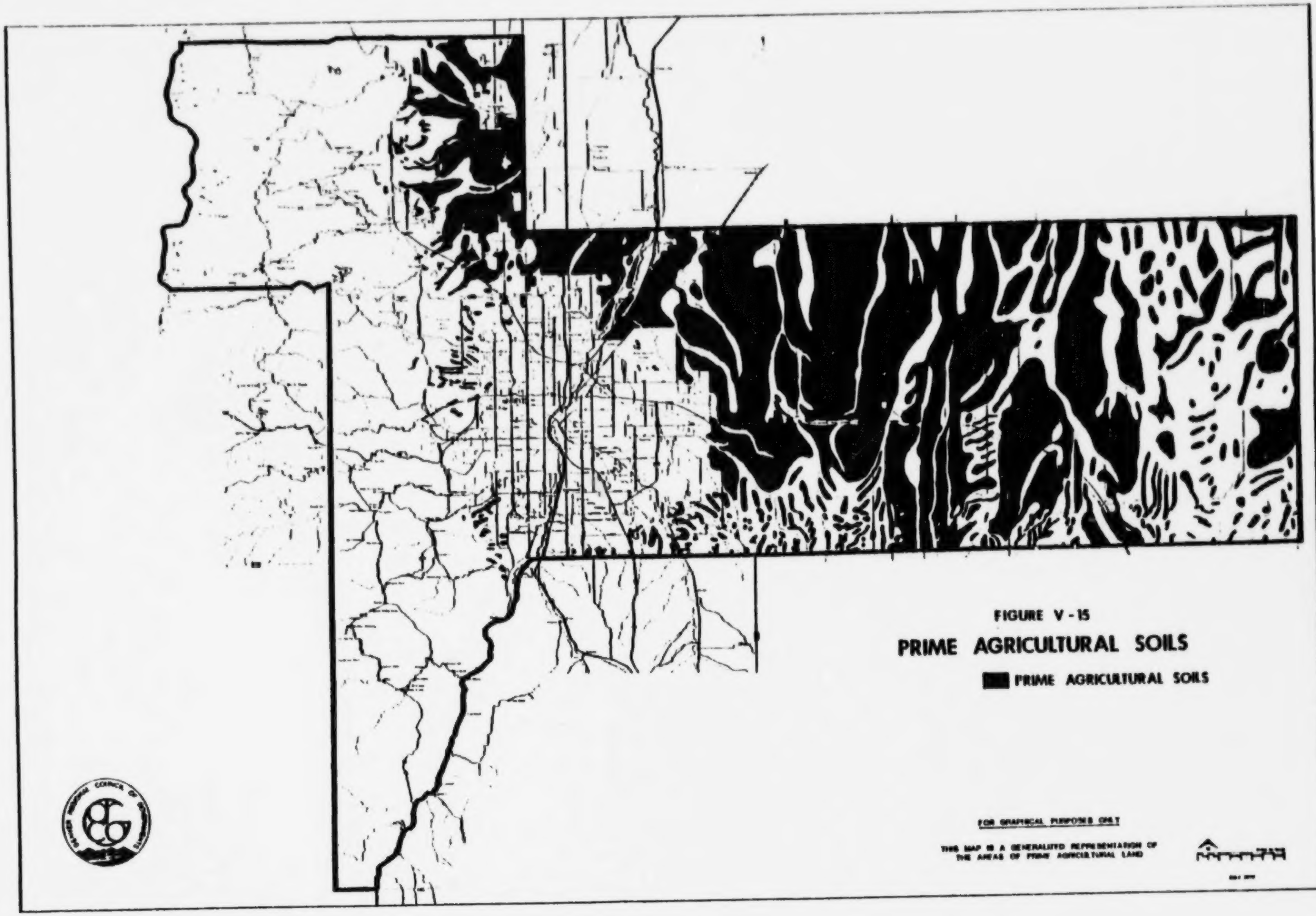

FIGURE V-15

PRIME AGRICULTURAL SOILS

■ PRIME AGRICULTURAL SOILS

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF
THE AREAS OF PRIME AGRICULTURAL LAND

BIBLIOGRAPHY FOR PRIME AGRICULTURAL LANDS

Sources Available at DRCOG

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This report includes maps and descriptions of all the soils in Adams County. The major fieldwork for the survey was done from 1963-1966. The soils information is mapped on a 1970 aerial photo base at a scale of 1:20,000.

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This report discusses problems of agricultural conversion and methods of preserving agricultural land in Minnesota.

"Erodibility and Loss Factors for Soils of Colorado," U.S. Department of Agriculture Soil Conservation Service, March 1975.

This technical report gives detailed soil information not contained in the soil survey. Data included is texture related to depth of the soil series, the soil erodibility factor (K) and the soil loss tolerance factor (T), which are both used in the universal soil loss equation, and the wind erosion group (WEG) classification.

"Critical Agricultural Lands Project" - draft project description by David Carlson, Colorado Department of Agriculture, August 1976.

This is the draft description of a project whose purpose is to identify the critical agricultural lands of the state of Colorado. These critical lands are those lands which have high inherent agricultural productivity which are currently or potentially in agricultural use, or lands which are under significant conversion pressure from such forces as urbanization, energy and minerals development , or transportation and recreation development.

"Identification and Preservation of Prime Agricultural Land" - Masters Thesis by Rex Burns, Department of Agronomy, Colorado State University, Fall 1975.

This report discusses the use of SCS capability classifications, a modified Storie productivity index, and a land utilization classification in identifying prime agricultural lands.

"Mesa County Agricultural Lands Workshop" October 6-7, 1976, Grand Junction, Colorado.

This information includes the agenda of the workshop and statements on the results from working sessions at the conference. Topics covered were agricultural land concerns of farmers, ranchers, citizens and local government. The conference was sponsored by the Mesa County Agricultural Study Group and the Rocky Mountain Center on Environment (ROMCOE).

A Report on the Environmental Resources of Boulder County, Colorado, by Ann R. FitzSimons, Boulder County Land Use Department, April 1977.

This report includes a section which describes the methodology used by the Boulder County planning staff to classify prime cropland and critical rangeland for Boulder County.

"Pawnee Grassland - A Land of Faded Dreams," by Bartell Nyberg - Empire Magazine, October 10, 1976.

This article stresses the importance of keeping large amounts of acreage on the plains in grasslands. These grasslands should be carefully managed when used as rangeland for grazing.

"A New Way to Plow Money Back Into Our Farmlands" by Wallace E. Washbon, American Society of Planning Officials "Planning" Magazine, November, 1976.

This article discusses the use of a transfer fee plan (TFP) and transfer of development rights (TDR) for preserving prime agricultural farmland.

Farmland Retention in the Metropolitan Washington Area, prepared for the Metropolitan Washington Council of Governments by Dallas D. Miner, June 1976.

This report is an examination of the status of the agricultural industry, rationale for the retention of farmland,and alternative preservation techniques. Special analysis is given to the problems and techniques of the preservation of prime agricultural lands in the metropolitan Washington, D.C. area.

"Use - Value Assessment of Farm and Open Space Lands," by Raleigh Barlowe and Theodore R. Alter, September 1976, Research Report #308 from the Michigan State University Agricultural Experiment Station.

This report discusses differential tax assessment policies, use-value tax assessment programs and deferred taxation as applied to agricultural lands for the purpose of preservation of those lands.

Agricultural Planning Handbook - Identifying Long-Term Productive Farm Land, by Metropolitan Council of the Twin Cities Area, July 1976.

This report is an excellent manual for addressing the problem of preservation of prime agricultural lands. It discusses methods to identify prime agricultural lands, recommended policies for agricultural areas and a discussion of agricultural land use law in the Twin Cities metropolitan area.

"Using Soil Information for Land Planning in Colorado," Colorado State University Experiment Station, Fort Collins, General Series 919, by Robert D. Heil and Joe Nichols, USDA, Soil Conservation Service, October 1971.

The report describes the data included in U.S. Department of Agriculture, Soil Conservation Service, County Soil Surveys. It also discusses ways in which information and interpretations in the soil survey can be used to make land use planning interpretations for areas which do not pose physical limitations for urban development.

"Farmland and Open Space Taxes: What Kind of Law for Wisconsin?" by Richard L. Barrows, University of Wisconsin-Extension, February 1975.

This report discusses some of the various types of taxes for agricultural and open space lands, what type of land should qualify for any preferential taxation, what type of roll-back tax there should be if the land is developed and changed from open or agricultural use and other factors that should be considered in developing a farmland or open space tax system for the State of Wisconsin.

"Lower Taxes for Farmland and Open Space," by Richard L. Barrows, University of Wisconsin- Extension, November 1974.

This report discusses various methods of preferential taxation for farmland and open space land. In addition it summarizes the use-value taxation laws of other states in the nation.

"Zoning to Preserve Agriculture: Columbia County," by Charles Deknatel and Susan Harris, Wisconsin State Planning Office, December 1974.

This report focuses in on the experience of Columbia County, Wisconsin in its efforts to preserve agricultural land through agricultural zoning.

Physical and Economic Effects on the Local Agricultural Economy of Water Transfer to Cities, by Dr. Raymond Anderson, Dr. Norman Wengert, Dr. Robert Heil, Dean Williams, Charles Palmer, and Ken McWilliams, NRED, Economic Research Service, USDA, Environmental Resources Center, Colorado State University, Completion Report No. 75, October 1976.

This report discusses the problems associated with competition for water by irrigation use and by expanding urban development. The study found that there would be a very significant decrease in agricultural production in the northern Denver region (west portions of Adams and Weld Counties and east portions of Jefferson County) if the irrigation water supply is removed for other uses. In addition, the expenditures for capital improvements spent by farmers for irrigated farming would be lost if that land reverted to dryland agriculture.

"Transfer of Development Rights: A New Land Use Policy for Wisconsin?" by Richard Barrows, Bruce Prenguber, and Douglas Yanggen, University of Wisconsin-Extension, Agricultural Economics Staff Paper No. 87, January 1975.

This report discusses the application of TDR (Transfer of Development Rights) for (1) guiding development on the urban fringe, (2) preserving historic landmarks, (3) protecting critical environmental resources, and (4) guiding development around public facilities.

"USDA Statement on Land Use Policy" - Secretary's Memorandum No. 1827, October 26, 1973, by Earl Butz, Secretary of Agriculture.

"USDA Policy on Prime Lands" - Secretary's Memorandum No. 1827, Supplement 1, June 21, 1976 - Statement of Prime Farmland, Range and Forest Land, by John A. Knebel, Acting Secretary of Agriculture.

This memorandum states the USDA policy will "advocate the protection of prime lands from premature or unnecessary conversion to other land uses."

"USDA Views on Farmland Retention," by Edward E. Thomas, Assistant Administrator for Land Resources, U.S. Department of Agriculture, January 3, 1977.

"Soaring Farmland Values: The Way Your State Compares," in U.S. News and World Report, February 7, 1977.

This article analyzes the per acre cost of farmland over the past five years and the drastic value increases in that time.

"Retention of Agricultural Land," Soil Conservation Society of America, Special Publication No. 19.

This report is a series of articles on preservation of agricultural land use taken from the Journal of Soil and Water Conservation.

Soil Resources of Colorado, Region 2 - Larimer and Weld Counties, Colorado State University Experiment Station, Fort Collins, Special Series 1-13, No. 1, in cooperation with USDA Soil Conservation Service.

This report and accompanying soil maps and graphs deals with the use of soil information in land planning. It identifies factors and limitations which are important to consider in contemplating varying land uses on specific soil types.

"Range Site Descriptions," Technical Guide Section IIE, U.S. Department of Agriculture Soil Conservation Service. Range site descriptions for:

- loamy plains
- loamy slopes
- deep sand
- sandy plains
- sandy bottomland
- salt flat
- overflow
- saline overflow
- wet meadow
- clayey plains
- shaly plains
- alkaline plains
- sandstone breaks
- gravel breaks
- loamy foothill
- rocky foothill
- clayey foothill
- sandy foothill

These range site descriptions include a discussion of the topography, climate, native vegetation, soils and wildlife common to each range site.

"Current Population Reports - Farm Population," Series Census - ERS, P-27, No. 48, April 1977. U.S. Department of Commerce, Bureau of the Census, U.S. Department of Agriculture, Economic Research Service.

This paper sets forth data on the decline of farm population throughout the United States.

"Federal Register," Volume 42, No. 163, August 23, 1977 - Proposed Rules U.S. Department of Agriculture, Soil Conservation Service, Part 657, Prime and Unique Farmlands - Important Farmland Inventory.

This proposed rule states general guidelines for a national program of inventorying prime and unique farmlands and other farmlands of statewide or local importance. It includes specific criteria for the definition of prime farmland.

"Soil and Water Resources Conservation Act of 1977," presented in the "Congressional Record," June 6, 1977.

The Use of Zoning to Retain Essential Agricultural Lands, by the Michigan Farm Bureau, Cooperative Extension Michigan State University, Center for Rural Manpower and Public Affairs Michigan State University, Division of Land Resource Programs Department of Natural Resources, September 1976.

This publication is specifically designed to serve as a technical manual which explains how zoning may be used to assist in the retention of lands which are essential to agricultural production in Michigan.

"T.D.R. What's Happening Now," in AIP, Practicing Planner, March 1977.

This report discusses the use of TDR (Transfer of Development Rights) for preservation of agricultural land. It analyzes the use of TDR in New York and New Jersey.

"Gaining Momentum! A Drive to Stop Suburban Sprawl" in U.S. News and World Report, March 21, 1977.

This article discusses the problem of conversion of agricultural land to urban uses and what several communities and counties are doing to slow that rate of conversion and preserve land in agricultural use.

"King County Agricultural Protection Program - Background and Effects of Ordinance 3064 Designating Agricultural Lands and Districts in King County, Washington," February, 1977.

This publication discusses the loss of agricultural land in King County, Washington and the resultant development of a county ordinance designating agricultural districts in the county.

"Council on Environmental Quality Memorandum - Analysis of Impacts on Prime and Unique Farmland in Environmental Impact Statements," by Russell W. Peterson, Chairman CEQ, August 1976.

This memorandum provides guidance to Federal agencies on how to evaluate the impact of major Federal agency actions on prime and unique farmland in the course of preparing environmental impact statements.

"Prime Lands - Definitional and Policy Problems," by William W. Wood Jr., Economist, Cooperative Extension University of California, Riverside, and Giannini Foundation of Agricultural Economics.

This report discusses problems in defining and identifying prime agricultural lands. It recommends that the definition of prime farmland take into account physical soil qualities, as well as aesthetic, economic, environmental and social variables.

"Identifying Prime Food and Fiber Lands," by William M. Johnson, Deputy Administrator, Soil Conservation Service, U.S. Department of Agriculture, March 23, 1977.

This paper describes U.S. Department of Agriculture programs and activities in support of the retention of prime farmland. It also discusses programs for the identification of prime farmland and the relationship of prime farmland to national agricultural policy.

"Water Conservation - Tips for Stretching Water on Crops and Soils," Soil Conservation Service, U.S. Department of Agriculture, February 1977.

This pamphlet gives information on pre-planting decisions such as which crops use less water. It also tells how to prepare soil to make the most of a short water supply.

"Water Conservation - Tips for Stretching Water on Pasture and Range," Soil Conservation Service, U.S. Department of Agriculture, February 1977.

This pamphlet indicates ways to save rangeland, livestock and wildlife during drought conditions.

OTHER SOIL REFERENCES NOT PRESENTLY AVAILABLE AT DRCOG

The Nature and Properties of Soils by Harry O. Buckman and Nyle C. Brady; seventh edition, 1971.

Soil Taxonomy, 1976.

AGRICULTURAL LAND MAPS

U.S. Department of Agriculture Soil Conservation Service, Soil Survey Maps of Adams County, Scale 1:20,000, Set of 94 Maps

USDA Soil Conservation Service, Soil Survey Maps of Arapahoe County, Scale 1:20,000, Set of 63 Maps

USDA Soil Conservation Service, Soil Survey Maps of Boulder County, Scale 1:20,000, Set of 31 Maps

Soil Conservation Service, Field Maps, Semi-detail map of Prime Agricultural Soils in Jefferson County, Scale 1:48,000

Land Use Maps - 1973, by U.S. Department of Agriculture Soil Conservation Service; Scale 1:126,720 (One inch = 2 Miles);
Maps for: Adams County
Arapahoe County
Boulder County
Jefferson County

These maps show irrigated cropland, non-irrigated cropland and rangeland.

Colorado Land Use Commission Maps, 1974
Potential for Irrigated Agriculture
Potential for Non-Irrigated Agriculture
Scale 1:500,000 (statewide maps)

Land Capability Map for Adams, Arapahoe, Boulder and Jefferson Counties
U.S. Department of Agriculture Soil Conservation Service
Prepared in January, 1959
Scale 1 inch = 1 mile

This map shows general soils information on soil type, soil parent material, slope and erosion classification.

Important Farmlands - Boulder County, Colorado
U.S. Department of Agriculture Soil Conservation Service
July 1977, Scale 1:100,000

This map shows areas of prime farmland, as designated by USDA SCS, in Boulder County.

Land Use and Natural Plant Communities - April 1976
U.S. Department of Agriculture Soil Conservation Service
Scale 1/2" = 1 mile (1:126,720)
Maps for: Adams County, Colorado
Arapahoe County, Colorado

These maps show irrigated cropland, non-irrigated cropland, natural plant communities and varying range sites.

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U.S. Customs House, Room 387
721 19th St.
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PARKS, RECREATION, AND OPEN SPACE

Criteria for Specification:

National Parks and Forests, State Parks and Recreation Areas, and the elements of the DRCOG Regional Parks, Recreation, and Open Space Development Plan (Regional Parks, Preserves, Trail Corridors, and Special Use Areas) have been designated as environmentally significant areas in the Denver Region.

Basis for Criteria:

National Parks and Forests, State Parks and Recreation Areas, and the elements of the DRCOG Regional Parks, Recreation, and Open Space Development Plan have been specified as environmentally significant areas in the Denver Region because those areas represent the major park, recreation and open space areas and facilities in the region. The following is a brief description of each of these areas:

A. National Forests

The Denver Region contains portions of three national forests, Arapahoe, Pike and Roosevelt, located in the western parts of Boulder and Jefferson Counties. A very small portion of the Arapahoe National Forest and approximately 106,500 acres of the Pike National Forest are found in Jefferson County. The southern third of Jefferson County is included in the Pike National Forest. Boulder County contains approximately 168,000 acres of the Roosevelt National Forest. These national forests are significant in providing recreational opportunities for picnicing, fishing, hiking, backpacking, camping, mountain climbing, skiing, and horseback riding.

B. National Parks

A portion (22,000 acres) of Rocky Mountain National Park is located in the northwestern corner of Boulder County. Rocky Mountain National Park annually attracts over 2.5 million visitors from the United States and many foreign countries. It provides similar recreational opportunities to the national forests.

C. State Park and Recreation Areas

Six of the 24 State Park and Recreation Areas in Colorado are located in the 5-County Denver Region[1]. These facilities range in size from 425 acres to 8,300 acres and serve a variety of recreational activities from passive nature observation to motorized vehicles. The State Park and Recreation Areas located in the Denver Region are:

1. Barr Lake

Located in northern Adams County, this lake environment provides no-wake boating facilities as well as a natural environment for education and photographic purposes. This state park encompasses about 2,500 acres including the lake and surrounding land area.

2. Golden Gate Canyon

Over 8,300 acres of this state park are located in Gilpin and Jefferson Counties. Oriented to hiking, horseback riding, and picnicing, this park also provides a nature education center which presents a summer program on the park environment.

3. Eldorado Canyon

This is the most recent addition to the state park system in the Denver Region and was established in order to protect Eldorado Canyon. Once completed, this park will include almost 3,400 acres of canyon, stream, and forest lands that will provide environments for rock climbing, hiking, and backpacking. The park is located in Boulder Canyon, south and west of the City of Boulder.

4. Arapahoe Motorized Park

Located in Arapahoe County east of Cherry Creek Reservoir, this 624 acre park was designed and constructed specifically for the motorbike and fourwheel drive vehicle. Obstacle courses here challenge the driving skills of operators of these recreational vehicles.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties

5. Chatfield Lake

Constructed for purposes of flood control on the South Platte River, this 5,600 acre park and lake provide a wide variety of outdoor recreation activities. Located at the junction of Douglas, Jefferson, and Arapahoe Counties, this park provides easy accessibility to most areas of the Denver metropolitan area .

6. Cherry Creek

This state park is located in the southeast part of the metropolitan area. The Cherry Creek reservoir provides excellent facilities for water skiing and sailing. Approximately 4,000 acres comprise this park and reservoir.

D. Regional Parks, Recreation, and Open Space Development Plan

In 1975, DRCOG was commissioned by the State of Colorado to develop the eight-county Planning and Management Region III (PMR-3) element of the Colorado Outdoor Recreation Plan. PMR-3 includes Douglas, Clear Creek and Gilpin Counties in addition to the 5-County DRCOG region. The Region III Plan was adopted by DRCOG in March of 1977, following a two year planning effort. The plan differs dramatically from preceding parks and recreation area plans in that it directs attention to the construction of a region wide system of trails for hiking, biking, and water related activities, as opposed to encouraging the acquisition of large land areas. In addition to the long term trails concept, the plan identifies implementation actions for the first five years.

The Region III Parks, Recreation, and Open Space Plans for 1980 and the Year 2000 were prepared in order to identify those areas within Region III that should be acquired and developed by a public or private agency to provide an outdoor recreation or open space facility. The outdoor recreation need priorities for 1980 for each county were related to specific sites, locations, and/or projects. The 1980 Parks, Recreation, and Open Space Plan addresses specific outdoor recreation needs and relates them to specific facilities. The Year 2000 Parks, Recreation, and Open Space Plan is a long range program for regional recreation open space that is concerned with recreational acquisition and development in broadly defined areas. The Year 2000 Plan does not address specific outdoor recreation activities or site specific facilities.

Neither the 1980 or 2000 plans specifically address the need for undeveloped open space as a means of environmental protection or urban growth shaping.

The 1980 Plan will represent the Region III component of the Colorado Statewide Comprehensive Outdoor Recreation Plan (SCORP) which is being developed by the State Division of Parks and Outdoor Recreation. The 1980 Plan describes the current projected outdoor recreation needs of Region III on a county-by-county basis and the extent to which existing facilities satisfy those needs. Three different regional corridor systems have been identified to address several outdoor recreation activities that have been identified as "needs" for 1980. These three systems are: the Regional Trail System, the Regional Bikeway System, and the Regional Waterway System.

The DRCOG Region III Parks, Recreation and Open Space Plan does not include smaller parks such as playgrounds and playfields, or neighborhood and community parks. The need for such parks is best determined at the local level and in almost all cases, local park planning and development is best carried out by agencies directly charged with responsibility for implementation.

Responsibility for acquisition and development of parks that serve the residents of more than one jurisdiction has been accepted by all levels of government. Because there is no uniform and widely accepted description of recreation facilities, an explicit classification of facilities was necessary to establish a framework for the regional plan. The elements of the Regional Parks, Recreation and Open Space Development Plan have been based on five classifications of regional parks. Each of these classifications was established to meet a specific regional outdoor recreation function. Only those sites or projects which meet the criteria of the following recreation classifications were included in the DRCOG Regional Parks, Recreation and Open Space Development Plan. The recreation classifications are as follows:

- Regional Park

  Areas of at least 100 acres that provide outdoor recreation facilities to more than one jurisdiction for picnicing, boating, fishing, swimming, hiking, bicycling, horseback riding, and camping. There are 12 existing and three proposed regional parks which range in size from 130 to 3,630 acres.

- Regional Park Preserve

  Area of natural environment of at least 400 acres that provides outdoor recreation opportunities to more than one jurisdiction for nature study, wildlife habitats, conservation, camping, backpacking, hiking, and fishing. There are currently 13 regional park preserves and seven proposed preserves. The regional park preserves range in size from 420 to 3,500 acres.

- Regional Trail Corridor

  Corridor developed to accommodate one or more modes of recreational travel such as hiking, bicycling, horseback riding, ski touring, snowshoeing, snowmobiling, trail biking, rafting, canoeing, or kayaking. A corridor is consistent with the Colorado Recreational Trail System classification and utilizes natural linear corridors as well as utility, railroad, highway, and drainage rights-of-way. A total of 167 miles of proposed trails are included in the PMR-3 plan for 1980.

- Regional Special Use Area

  Area that provides a specialized or single purpose outdoor recreation facility that is unique to the region. There are ten existing special use areas including the Denver Zoo and County Fairgrounds. No new special use areas were proposed as part of the Plan.

Regional Historic Parks were also defined as elements of the Regional Parks, Recreation and Open Space Development Plan. These areas which are historic districts officially designated by the State Historical Society and/or the National Register of Historic Places have been designated as environmentally significant under "Historical Places".

Those regional parks, regional park preserves, regional trail corridors and regional special use areas which are located in the five-county Denver Region are listed in Appendix A.

Parks, recreation and open space areas have been designated as environmentally significant areas for a number of reasons. Parks, recreation sites and open space areas preserve visual open space and provide areas and opportunities for people to enjoy their leisure time. In today's society, the quantity and quality of leisure time is carefully considered. People are constantly discovering ways to use their leisure time whether it be noon hours, evenings, weekends, or vacations. The climate of the Denver area and its accessibility to mountain areas both contribute to the importance of leisure time to the population of the metropolitan area. The relatively mild climate permits the practice of a wide range of outdoor recreation activities and in turn increases the demand for such activities.

Recent years have shown large increases in the demand for recreation areas and activities. This increased demand is largely the result of increases in population, leisure time, disposable income and mobility. With the anticipated growth of population in this region, it is expected that recreational demand will also increase substantially. According to Resources for the Future, Inc., a non-profit organization endowed by the Ford Foundation:

> "America, by the end of the century, when twice as many people will be trying to enjoy about half again as much leisure time as they now have, on about double their present income and travel budget, will need perhaps four times the number of in-city parks and playgrounds, 16 times as many regional parks and lakes close enough for a day's outing, and roughly 40 times the amount of land that is in national parks, scenic spots, and forest areas now being badly over-trampled."

Recreation and open space areas within the urban areas of the Denver Region are used regularly by all age and interest groups of the population. In fact, this region is often thought of nationally as an outdoor recreation and vacation capital. People are attracted to the recreational opportunities of this area from all over the nation because of the beautiful mountain scenery, the easily accessible skiing and mountain recreation opportunities, and the wonderful climate. The quality physical environment of this region and of Colorado is one of the major reasons for living here.

Open space is a fundamental element in any decent and desirable living environment. No other single land-use feature is more important in establishing the setting, character, and form of an urban area. In the Denver region, open space has not yet been considered a serious problem. The mountains, foothills, and plains areas offer an abundance of useful as well as visual open space. However, within the urbanized areas, open space environments are rapidly disappearing due to rapidly expanding residential and commercial developments. The problem then, of many communities, is how to properly preserve, reclaim, and make available for use in appropriate locations and quantities, the open space that is left. Such open space preservation will serve three functions:

1. Recreation: Open space lands can provide areas for park and recreation activities and vice versa.

2. Conservation: Open space lands can conserve and protect environmentally sensitive natural or historical areas for the benefit of future generations. The National Environmental Policy Act (NEPA) and Colorado Land Use Act (HB 1041) have brought to attention the necessity for preserving and protecting our valuable natural resources and our historic heritage. Floodplains and geologic hazard areas are among the "natural hazard" areas which counties must designate and ultimately manage under the provisions of HB 1041. Counties must also designate areas containing, or having significant impact upon, historical, natural or archaeological resources of statewide importance. Similarly, the NEPA requires protection of such ecological sensitive areas as wetlands, wildlife habitats, and forests. Utilizing park and recreation lands to achieve the objectives of state and federal conservation laws may produce multiple benefits for the dollars invested.

3. Shaping Urban Environment: Open space areas can bring a natural environment to city dwellers, provide relief from extensive urbanization, define the boundaries of municipalities and districts, prevent excesses of urban sprawl, and provide beauty and character to an urban area.

To maintain the recreational quality of life which has earned a very special reputation in the Denver region, there will have to be increasing future investments in parks, recreation and open space areas and facilities.

MAPPING STUDIES USED IN DESIGNATING PARK, RECREATION, AND OPEN SPACE AREAS IN THE DENVER REGION

Parks, Recreation and Open Space
    Denver Regional Council of Governments
    January 1976
    Scale 1 inch = 1 mile (1:63, 360)
    Map includes metropolitan corridor area

Region III Parks, Recreation and Open Space
    Denver Regional Council of Governments
    January 1976
    Scale 1 inch = 2 miles (1:126, 720)
    Map includes Adams, Arapahoe, Boulder, Clear Creek, Denver, Douglas, Gilpin and Jefferson Counties

National Forest Maps, Colorado
    U.S. Forest Service
    Scale 1 inch = 2 miles (1:126, 720)
    Maps for: Arapahoe National Forest
    Pike National Forest
    Roosevelt National Forest

APPENDIX A

EXISTING AND PROPOSED REGIONAL PARK FACILITIES IN THE DENVER REGION

Regional Parks

Boulder Reservoir (City of Boulder)
Standley Lake (Westminster)
North Jeffco Mountain Park
Camenisch Park (Hyland Hills Park District)
Stonehocker Park (Northglenn)
Belmar Park (Lakewood)
Hayden Park (Lakewood)
Sloan Lake Park (Denver)
Washington Park (Denver)
Springhill Park (Aurora)
Quincy Reservoir (Aurora)
*Bear Creek Lake (Foothills Park District)
*Marshall Lake (City of Boulder)
*Haystack Mountain (Boulder County)

Regional Park Preserves

Hidden Valley Ranch (City of Boulder)
Bear Mountain (City of Boulder)
Green Mountain (City of Boulder)
Flagstaff Mountain (City of Boulder)
Genessee Park (Denver)
Bell Park (Denver)
Dedisse Park (Denver)
Little Park (Denver)
O'Fallon Park (Denver)
Mt. Falcon Park (Jefferson County)
White Ranch (Jefferson County)
Reynolds Ranch (Jefferson County)
Daniels Park (Denver)
*Green Mountain (Jefferson County)
*Grant Ranch (Jefferson County)
*Arsenal Lands (Adams County)
*Means Meadow (Jefferson County)
*South Table Mountain (Slopes)
*Betasso Preserve (Boulder County)
*Rock Creek Basin (Boulder County)

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* Proposed.

Regional Trail Corridors

South Platte River
Clear Creek
Cherry Creek
Bear Creek
Highline Canal
Sand Creek
Tollgate Creek
Big Dry Creek
Coal Creek
Boulder Creek
South Boulder Creek
St. Vrain River
Red Rocks Trail
Beaver Brook Trail
Apex Gulch
Little Dry Creek
Goldsmith Gulch
Hogback Trail
Ralston Creek
Farmer's Highline Canal
O'Brian Canal
Foothills Trail
Colorado Trail
Colorado Mountain Trail
Continental Divide Trail
Willow Creek
St. Vrain Creek
State Highway 93
Sanderson Gulch
Weir Gulch
Lakewood Gulch
Highline Canal
Leyden Creek
Old Golden Road
Chimney Gulch
Fairgrounds Trail
Alameda Parkway
Cold Springs
Evergreen to Pence Park
Columbine Trail
Van Bibber Creek
State Highway 7
Brighton to Barr Lake
State Highway 83
Lyons to Nederland

Regional Trail Corridors (Cont'd)

Boulder Canyon
Lyons North
State Highway 66
Hover Road
Longmont Diagonal
State Highway 52
Baseline Road
U.S. Highway 36
State Highway 128
State Highway 72
South Boulder Canyon (State Highway 398)
Coal Creek Canyon (State Highway 72)
Indiana Street
Golden Gate Canyon Road
Clear Creek (U.S. Highway 6)
Union-Simms
Wadsworth Boulevard
Hogback Road
U.S. Highway 40
Bergen Park
State Highway 74
State Highway 8
U.S. Highway 285
South Turkey Creek
Evergreen to Aspen Park
Glen Elk
Pine to Deckers
Deer Creek Canyon
Old Golden Road

Regional Special Use Areas

City Park - Denver (Zoo, Museum)
Cheesman Park - Denver (Botanic Gardens)
County Fairgrounds - Adams
- Arapahoe
- Boulder
- Douglas
- Jefferson

Red Rocks Park - Denver (Amphitheater)

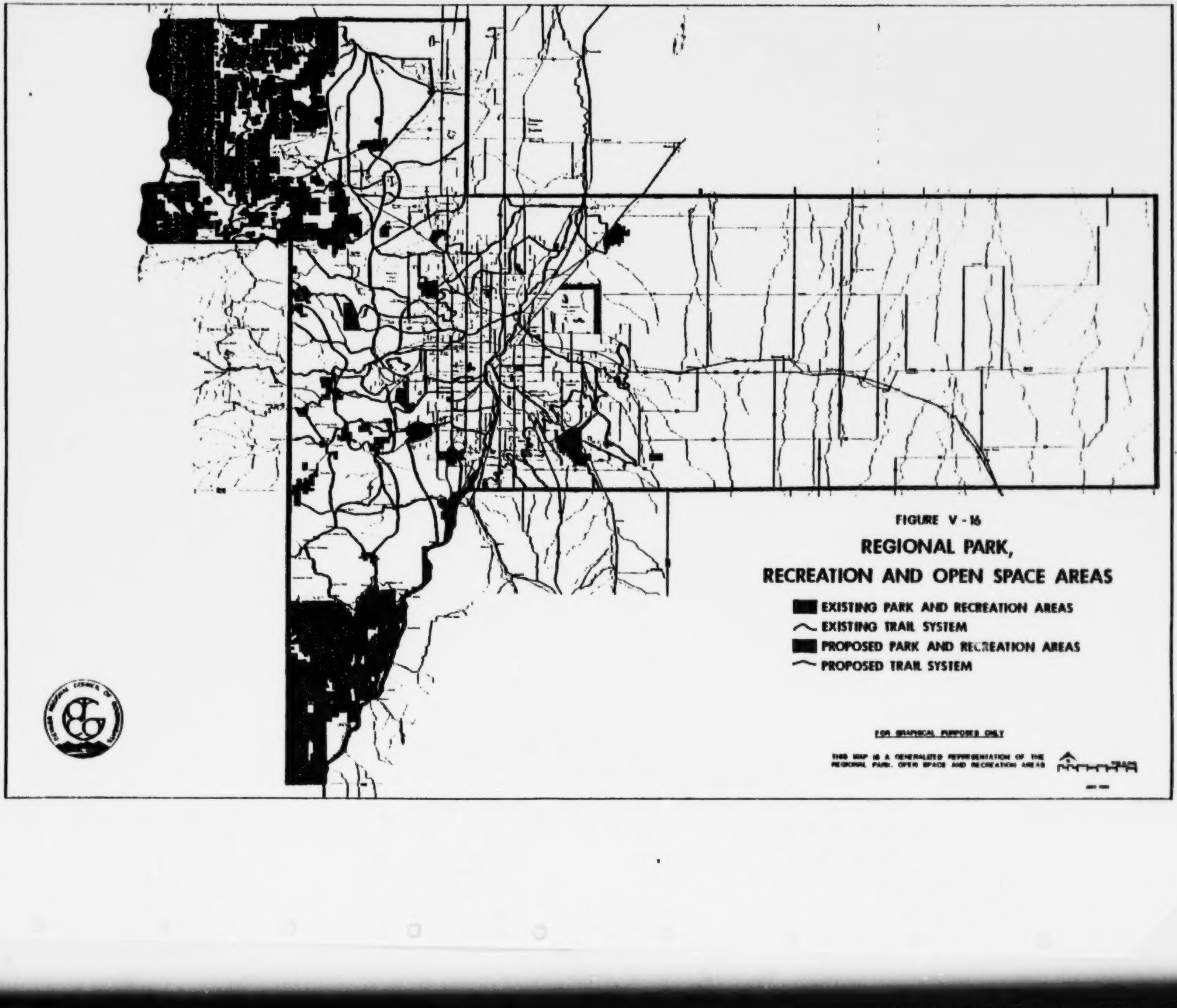

FIGURE V - 16

REGIONAL PARK, RECREATION AND OPEN SPACE AREAS

■ EXISTING PARK AND RECREATION AREAS
～ EXISTING TRAIL SYSTEM
■ PROPOSED PARK AND RECREATION AREAS
～ PROPOSED TRAIL SYSTEM

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION OF THE REGIONAL PARK, OPEN SPACE AND RECREATION AREAS

BIBLIOGRAPHY FOR PARKS, RECREATION AND OPEN SPACE

Sources Available at DRCOG

PARK, RECREATION AND OPEN SPACE REFERENCES

Region III Regional Parks, Recreation, and Open Space Development Plan, by Fred Wolfe, Denver Regional Council of Governments, March 1977.

This plan was prepared to identify areas in Region III that should be acquired and developed by public and private agencies to provide needed park, outdoor recreation or open space opportunities through the years 1980 and 2000.

Regional Parks, Recreation, and Open Space Plan, Phase I, State Planning and Management Region III, Denver Regional Council of Governments, December 1975.

This report identifies both regional and county outdoor recreation needs, identifies and maps existing outdoor recreation facilities, and sets forth open space objectives for Region III.

Regional Parks, Recreation and Open Space Plan, Phase 1, Volume II - Technical Appendix, State Planning and Management Region III, by Denver Regional Council of Governments, December 1975.

Parks, Recreation, Open Space Development Program, Denver SMSA, Report 8703, December 1970, Denver Regional Council of Governments.

This report relates the short range (5-10 year) resource and development program for parks and open space to the many agencies in the Denver region dealing with provision of park, recreation and open space facilities. It identifies existing park deficiencies throughout the region and develops priorities for land acquisition.

Supplement: 1970 Parks and Recreation Open Space Development Program, Denver SMSA, January 1973, Denver Regional Council of Governments.

This supplement to the 1970 plan reviews park standards and criteria and proposes revised park standards and criteria. It also sets forth park and recreation needs to the year 2000.

Regional Open Space Plan, Denver Metropolitan Region - Volume I, Denver Regional Council of Governments, December 1968.

Regional Open Space Plan, Denver Metropolitan Region - Volume II, Denver Regional Council of Governments, December 1968.

Regional Open Space Plan, Denver Metropolitan Region - Summary Report, Denver Regional Council of Governments, December 1968.

This study projects park and recreation needs to the year 2000.

"Directory of Local Park and Recreation Agencies, Inventory of Local Park and Recreation Areas and Facilities, Inventory of Open Space and Open Space Areas in Boulder County," Inter-County Regional Planning Commission, January 1968.

"Directory of Local Park and Recreation Agencies, Inventory of Local Park and Recreation Areas and Facilities, Inventory of Open Space and Open Space Areas in the Denver Region," Inter-County Regional Planning Commission, August 1966.

"Park and Recreation Proposals," Inter-County Regional Planning Commission, April 1964.

PARKS, RECREATION AND OPEN SPACE MAPS

National Forest Maps, Colorado
U.S. Forest Service
Scale 1/2 inch = 1 mile (1:126,720)
Maps for: Arapahoe National Forest
Pike National Forest
Roosevelt National Forest

Jefferson County Open Space Map
Jefferson County Open Space Program
Scale 1 inch = 3 miles

Forest Type Maps (Township)
U.S. Forest Service
Pike National Forest
Scale 1 inch = 1/2 mile (1:31,680)
Maps for the following townships:

T6S,R72W
T7S,R69W
T7S,R70W
T7S,R71W
T7S,R72W
T8S,R69W
T8S,R70W
T8S,R71W
T8S,R72W
T9S,R69W
T9S,R70W
T9S,R71W
T9S,R72W
T10S,R70W
T10S,R71W

Parks, Recreation and Open Space Map
Denver Regional Council of Governments, January 1976
Scale 1 inch = 1 mile (1:63,360)
(Metropolitan corridor area)

Region 3, Parks, Recreation and Open Space
Denver Regional Council of Governments
Scale 1 inch = 2 miles (1:126,720)
Map includes Adams, Arapahoe, Boulder, Clear Creek, Denver, Douglas, Gilpin and Jefferson Counties.

Boulder Mountain Parks
Chautauqua/Flagstaff
City of Boulder Parks and Recreation Department, January 1976
Scale 1 inch = 800 feet (1:9,600)

Boulder City Parks
City of Boulder
Scale 1 inch = 1,000 feet (1:12,000)

Boulder Reservoir Site Development Plan
Scale 1 inch = 200 feet (1:2,400)

Hidden Valley Ranch
City of Boulder Parks and Recreation Department
Scale 1 inch = 300 feet (1:3,600)

Adams County Proposed Trail System
Scale 1 inch = 1.5 miles

Adams County Regional Park
Adams County Planning Department
    2010 Conceptual Plan
    Scale 1 inch = 400 feet (1:4,800)
        1 inch = 1,000 feet (1:12,000)

    1990 Conceptual Plan
    Scale 1 inch = 400 feet (1:4,800)

    Existing Facilities
    Scale 1 inch = 400 feet (1:4,800)

City of Boulder Greenbelts
Scale 1 inch = 1,000 feet (1:12,000)

City of Northglenn
Master Plan - Civic Center and Related Open Space, 1975

Westminster Open Space Map, 1974
Scale 1 inch = 2,000 feet (1:24,000)

Boulder County
Public Ownership Map
Scale 1 inch = 3 miles

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HISTORICAL PLACES

Criteria for Specification:

Those historical structures, sites and districts which have been designated on the National and State Registers of Historic Places have been designated as environmentally significant in the Denver Region.

Basis for Criteria:

The preservation of historic structures and sites is vital to the prevention of architectural sterility and monotony in the communities of the Denver Region.[1] Historical preservation efforts in this area have been frustrated by the rapid redevelopment of older areas of business and residential districts. Numerous structures of significant historical and architectural importance have been demolished to provide space for yet another sterile office building or a paved parking lot. These instances of demolition, however, have decreased in recent years due to the persistent efforts of both state and local historical preservation organizations.

There are numerous historic structures, sites and districts within the Denver Region. A historic structure is a specific building for which historic designation has been given and preservation efforts have been initiated. Examples of historic structures include a structure associated with a notable person, or the work of a master architect or builder, or a builder of particular significance to a certain locality. A historic structure might represent a particular style that typifies or is indigenous to a certain locality or that is a significant surviving example of a style that is becoming rare in a certain location. Historic structures may include homes, boarding houses, stores, taverns, mills, silos, mines, jails, post offices and other governmental buildings, churches, chapels, kivas, theaters, museums, schools, forts, campsites, bridges, carriage houses and many other types of structures.

A historical site is the distinguishable geographical location of an event or activity which is of historic or prehistoric significance. Examples of historical sites include ghost towns, early exploration routes, parks, battlegrounds, cemetaries, foundations, mountain passes, historical trails, and railroad routes.

A historic district is an urban or rural area which possesses a concentration of structures, sites or objects which are unified historically or aesthetically by plan, physical development or occupation.[2] A historical district may be a collection of buildings and open spaces that expresses or contributes to the historical character of an area or that expresses a unity of historical period and architectural style. Examples of historical districts include commercial streetscapes, residential neighborhoods of particular significance, ranch buildings, and mining districts.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

The history of the Denver Region can be traced back to 1858 when gold was discovered in the riverbed at the mouth of Dry Creek in what is now Englewood adjacent to the South Platte River. With the subsequent discoveries of rich lodes of gold ore in the nearby mountains and the development of railroad service, Denver's economy was stimulated and produced many significant examples of residential, religious, and commercial architecture. Historic preservation in Colorado and particularly in the Denver metropolitan area is currently accomplished on three levels: Federal, State, and local. Those structures, sites, and districts that have been officially designated by State and Federal agencies for their historical value are considered to be of regional significance. A brief summary of each one of these levels is as follows:

Federal--The first legislative action for historic preservation on the national level occurred in 1935 with the passage of the Historic Sites Act. This Act designated the Secretary of the U.S. Department of Interior to conduct through the National Park Service, a national survey of sites of exceptional value in United States history. An expansion of this mandate was established in 1966 with the passage of the National Historic Preservation Act. The Act authorized "the Secretary of the Interior to expand and maintain a national register of districts, sites, buildings, structures and objects significant in American history, architecture, archeology and culture, herein after referred to as the National Register...." This Act also established a program of matching grants-in-aid to the states.

In May of 1971, the role of the Federal Government in historic preservation activities was further emphasized with the signing of Executive Order 11593, entitled "Protection and Enhancement of the Cultural Environment." This order states that: "The Federal Government shall provide leadership in preserving, restoring and maintaining the historic and cultural environment of the nation." Under Section 2 (a) of the Order, the heads of Federal Agencies shall: "....with the advice of the Secretary of Interior, and in cooperation with the liaison officer for historic preservation for the state or territory involved, locate, inventory, and nominate to the Secretary of the Interior all sites, buildings, districts, and objects under their jurisdiction or control that appear to qualify for listing in the National Register of Historic Places." This Executive Order also directs agencies to see to it that properties which are listed on the National Register are suitably protected.

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[2] Guidelines for Identification and Designation of Historical, Natural and Archeological Resources, by the State Historical Society of Colorado, 1974.

The National Environmental Policy Act of 1969 establishes criteria for the expenditure of federal funds such that the nation's cultural and natural resources will be protected and enhanced. The criteria are published as guidelines for the preparation of Environmental Impact Statements which are required on federally funded or licensed projects deemed to have a major impact on the environment.

The Department of Housing and Urban Development requires that planning activities funded under Section 701 of the Housing Act of 1954, as amended, be carried out in accord with Section 106 of the National Historic Preservation Act of 1966, Executive Order 11953 and Section 101(b) (4) of the National Environmental Policy Act of 1969. HUD regulations require the inclusion of historic preservation and enhancement in the comprehensive planning process.

The National Register of Historic Places is a list of historical, architectural and archaeological places that have recognized value in the history of the locale, the state, or the nation.[3] Historical sites in the National Register are documented by descriptions and photographs of the site which are kept in Washington D.C. by the National Park Service (U.S. Department of Interior). Potential entries to the National Register of Historic Places are evaluated by the National Park Service using the following criteria:

> The quality of significance in American history, architecture, archeology, and culture is present in districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and:
>
> 1. That are associated with events that have made a significant contribution to the broad patterns of our history; or
>
> 2. That are associated with the lives of persons significant in our past; or

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[3] _Ibid_., State Historical Society of Colorado.

3. That embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

4. That have yielded, or may be likely to yield, information important in pre-history or history.

Ordinarily cemeteries, birthplaces, or graves of historical figures, properties owned by religious institutions or used for religious purposes, structures that have been moved from their original locations, reconstructed historic buildings, properties primarily commemorative in nature, and properties that have achieved significance within the past 50 years shall not be considered eligible for the National Register. However, such properties will qualify if they are integral parts of districts that do meet the criteria or if they fall within the following categories:

1. A religious property deriving primary significance from architectural or artistic distinction or historical importance; or

2. A building or structure removed from its original location but which is significant primarily for architectural value, or which is the surviving structure most importantly associated with a historic person or event; or

3. A birthplace or grave of a historical figure of outstanding importance if there is no other appropriate site or building directly associated with his productive life; or

4. A cemetery which derives its primary significance from graves of persons of transcendent importance, from age, from distinctive design features, or from association with historic events.

Inclusion on the National Register of Historic Places makes private property owners eligible to be considered for Federal grants-in-aid for historic preservation through State programs. It also provides protection through comment by the Advisory Council on Historic Preservation on the effect of federally financed, assisted, or licensed undertakings on historic properties, as stated in Section 106 of the National Historic Preservation Act of 1966 and Executive Order 11593.

State--The State Historical Society of Colorado was founded in 1879. This organization is currently funded by the State Department of Higher Education. A Board of Directors composed of 12 private citizens (appointed) governs the society's activities. This organization coordinates its preservation efforts with both the Federal and local levels. The State Historic

Preservation Officer, of the State Historical Society, is appointed by the Governor to speak officially in behalf of the State on matters relating to historic preservation. The National Preservation Act is implemented in cooperation with the State Historic Preservation Officer, who is responsible for administering the National Register program within his or her jurisdiction.

Before properties are nominated for inclusion in the National Register, a statewide survey of historic, architectural, archeological, and cultural resources is undertaken. The State Hisotrical Society of Colorado has conducted and periodically updates a county-by-county inventory of Colorado historic structures, sites, and districts. Entry on the National Register automatically places the property on the State Register of Historic Properties and protects it against adverse actions by state agencies. However, a state historic property is not automatically placed on the National Register. State nominations to the National Register are evaluated using the same criteria as was previously mentioned under the Federal discussion.

Before submission to the National Register, all State nominations must have been approved by the State Review Board whose membership includes architects, historians, and archeologists. The State Historic Preservation Officer and the State review board are responsible for the preparation and review of the State's historic preservation plan which includes background information on the State, an inventory and analysis of the State's historic resources, and a program for their protection. The National Park Service, acting in behalf of the Secretary of the Interior, reviews the plan and gives approval. Each State has an opportunity to annually update the content of the basic plan.

The five-county Denver region currently contains 607 individual historic places that have been designated by the Colorado State Historical Society.[4] Of these 607 places, 83 historic places are on the National Register of Historic Places. The counties of this region include the following numbers of State and National Register historic sites, structures and districts:

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[4] Statewide Inventory of Historic Sites, Updated through March 1977, State Historical Society of Colorado.

	Structures		Sites		Districts		Total	
County	State/Federal		State/Federal		State/Federal		State/Federal	
Adams	21	0	20	0	0	0	41	0
Arapahoe	50	0	10	1	0	0	60	1
Boulder	70	3	26	0	2	1	98	4
Denver	252	49	19	0	10	7	281	56
Jefferson	85	18	38	1	4	3	127	22
Total	478	70	113	2	16	11	607	83

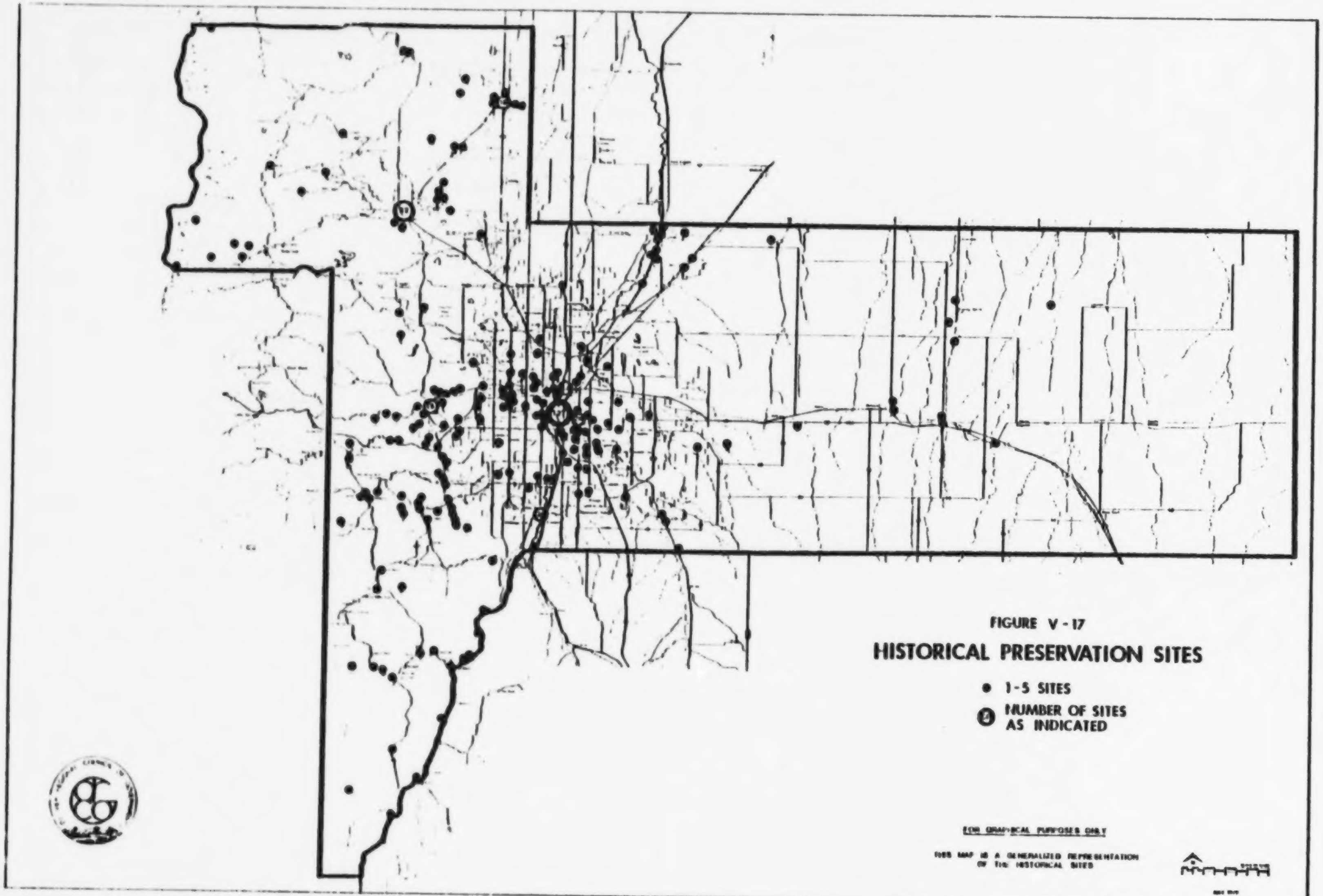
Local--The interest in identifying structures, sites, and districts on the local level range from a large established group such as the Denver Landmark Preservation Commission to small local historic groups such as the Commanche Crossing Historical Society in Strasburg, Colorado. The five counties in the Denver Region contain approximately 25 local historic preservation organizations. Each one of these organizations directs its efforts toward preserving the important elements of the community's cultural, architectural, and historical heritage. These local organizations also coordinate their activities with the State Historical Society of Colorado. A list of the historic preservation organizations in the Denver Region is included in the Bibliography.

Historical places have been designated as environmentally significant areas because they represent significant examples of our environment through a certain time period. A main objective in protecting areas of historical significance is to promote and retain a sense of perspective in our environment which is appreciative of finite remains of past history. Historical structures, sites and districts represent a compilation of worthwhile elements that contributed to the physical and cultural environment in which we live and consequently they should be protected to preserve the many things they portray.

STUDIES USED IN DESIGNATING HISTORICAL PLACES IN THE DENVER REGION

"Statewide Inventory of Historic Sites - Updated Through March 1977," by the State Historical Society of Colorado.

This inventory was prepared in January 1976 and updated in April 1976, June 1976, October 1976, December 1976, and March 1977. This inventory lists the specific location of each historical site, structure or district included in the inventory. From these written descriptions, the locations of the 607 historic places in the Denver Region were plotted on U.S.G.S. quadrangle maps at a scale of 1 inch equals 2000 feet.



● 1-5 SITES
⓿ NUMBER OF SITES AS INDICATED

FIGURE V - 17

HISTORICAL PRESERVATION SITES

FOR GRAPHICAL PURPOSES ONLY

THIS MAP IS A GENERALIZED REPRESENTATION
OF THE HISTORICAL SITES

COAL RESOURCES

Criteria for Specification

Two classifications of areas containing coal have been used for designation of environmentally significant areas of coal deposits in the Denver Region. One classification, entitled Prime coal resource areas for the purposes of this plan, are those areas which based on existing studies and data, appear to meet the national criteria for classification as a Coal Reserve Base. These areas, in the Denver Region,[1] contain beds of subbituminous coal, 60 inches or more thick that occur at depths to 1,000 feet and can also include thinner and/or deeper beds of subbituminous coal that are presently being mined or for which there is evidence that they could be mined commercially at this time. The national classification of Coal Reserve Base also includes beds of lignite 60 inches or more thick which can be surface mined--generally those that occur at depths no greater than 120 feet.

The other classification of coal deposits is entitled Potential coal resource area and includes those areas of coal in the region which do not meet the national criteria for Coal Reserve Base or for which there is not significant information on the deposit to classify it as a Coal Reserve Base. Also included are those areas containing coal deposits which do not appear commercially feasible at this time but which may be so in the future with changes in fuel demands, market conditions, and fuel processing and mining technologies.

Basis for Criteria

At the present time, detailed information on the quantity, quality, and commercial feasibility of coal deposits in this region is somewhat deficient. Several studies on coal resources in the State of Colorado and on specific coal beds have been completed in the past decades. However, no region-wide detailed data exists at this time on the specific location of coal deposits, the thickness of the coal beds, the amount of non-coal material in the coal beds and the thickness of overburden to the resource. Consequently, it is impossible to present a detailed picture of this data for the DRCOG region at this time. Some studies on coal deposits are presently in progress by the Colorado Geological Survey. However, these studies will not be complete for several years.

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[1] Adams, Arapahoe, Boulder, Denver and Jefferson Counties.

A problem in portraying coal resource information is the variability of what is actually a "potentially commercial" coal resource. In most instances, the criteria used for determining the economic feasibility of mining a given coal resource depends upon a multitude of extremely variable factors. Among these factors are thickness of the coal bed, depth and type of overburden material, the rank of the coal and its value for heating and other uses, market supply and demand, transportation routes in close proximity to the coal resource, present mining technologies, existing environmental standards, ease of site reclamation and the variability of resource quality within the coal bed.

Most mining companies have developed their own technologies and specific mining strategies and techniques as well as their own criteria for evaluating the potential commercial value of a deposit. Most coal mining companies keep their information and criteria confidential for fear that the information will be used by other competitive mining companies.

Some Federal standards do, however, exist for classifying coal resources and coal reserves. A coal resource classification was developed by the U.S. Department of Interior, Bureau of Mines and the U.S. Geological Survey and has been used in preparing coal resource and coal reserve estimates by the Department of Interior since January 1, 1975.[2] The estimates of the different classes of coal resources and reserves are based upon thickness, rank and quality of the coal bed, depth from the ground surface to the coal bed, and the proximity of the actual coal resource data points upon which the estimate of reserve or resource was based. The depth to the coal bed and the thickness of that bed are criteria because these factors control the economic and technologic feasibility of recovery. Criteria have been designated for anthracite, bituminous coal, subbituminous coal and lignite. However, this report will only address the national criteria regarding subbituminous coal and lignite because those are the only types of coal which have been identified to exist in this region.

The following are the Department of Interior's criteria for coal resource/coal reserve classification of subbituminous coal and lignite:

> Identified Resources: Includes beds of subbituminous coal and lignite 30 inches or more thick that occur at depths to 6,000 feet and whose existence and quantity have been delineated within

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[2] "Coal Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey," Geological Survey Bulletin 1450-B, published in 1976.

specified degrees of geologic assurance as "measured," "indicated," or "inferred." Also included are thinner and/or deeper beds that presently are being mined or for which there is evidence that they could be mined commercially.

Undiscovered Resources: Includes beds of subbituminous coal and lignite 30 inches or more thick that are presumed to occur in unmapped and unexplored areas to depths of 6,000 feet.

Reserve Base: Includes beds of subbituminous coal 60 inches or more thick that occur at depths to 1,000 feet. Includes also thinner and/or deeper beds that presently are being mined or for which there is evidence that they could be mined commercially at this time. Includes beds of lignite 60 inches or more thick which can be surface mined--generally those that occur at depths no greater than 120 feet.

Reserve: Includes that portion of the Reserve Base that can be mined at the time of classification. The Reserve is derived by applying a recovery factor to the Reserve Base. The recovery factor varies with the type of mining technique used and the physical characteristics of the deposit and its location. On a national basis a 50% recovery factor is representative for underground mining. The recovery factor for surface mining is greater and ranges from 50% to 90%.

Subeconomic Resources: Includes all Identified Resources that do not fall into the Reserve category. Includes beds of subbituminous coal 30 inches to 60 inches thick that occur at depths to 1,000 feet. Includes also beds of subbituminous coal 30 inches or more thick that occur at depths between 1,000 feet and 6,000 feet. Includes lignite beds 30 inches or more thick that cannot be surface mined--generally those that occur at depths greater than 120 feet, and lignite beds 30 inches to 60 inches thick that can be surface mined. Includes the currently nonrecoverable portion of the Reserve Base.

Those coal deposits which appear to meet the national criteria for classification as a Coal Reserve Base are designated as Prime coal resource areas in this region and are listed in Appendix A. Appendix A includes a listing of the townships which appear to meet the criteria for Coal Reserve Base as well as an estimate of the amount of coal in each township. Those coal deposits which fall into the other categories described above are designated as Potential coal resource areas in this region and are listed in Appendix B. Appendix B lists the general mapping studies which show the locations of coal deposits in the region.

Coal is defined as a readily combustible rock which contains more than 50 percent by weight and more than 70 percent by volume of carbonaceous material formed from compaction of variously altered plant remains.[3] The plant matter of which coal is composed accumulated in ancient swamps and was buried by younger sediments. The accumulation of the organic plant remains and other inorganic mineral matter was in a manner similar to that in which modern-day peat deposits are formed. This peat material then underwent a long extremely complex process called "coalification" during which diverse physical and chemical changes occurred as the peat changed to coal.[4] Time, temperature and pressures produced by deep burial and sometimes by earth movement, gradually transforms the organic matter into coal. During this process, the percentage of carbon increases as the volatile hydrocarbons and water are forced out of the deposit. Coals are ranked according to the percentage of carbon they contain and the carbon content increases the longer the material has undergone decay. Lignite has the least amount of carbon and is the lowest ranking; next comes subbituminous coal, bituminous coal and finally anthracite which has the highest percentage of carbon.

The ranking of coal is generally related to the geologic age of the coal bearing formation because the older coal beds have, in general, been subjected to a greater amount of crustal deformation and also a greater amount of weight from overlying strata than have younger coals and consequently they are of a higher rank. Coal is classified not only by rank (percentage of fixed carbon and heat content), but also by grade or quality which is the content of sulfur, ash and other deleterious constitutents within the coal. Most coals are burned to produce heat energy and consequently the heating value of the coal is also an important property. The heating value is usually expressed in British thermal units (Btu) per pound.

Most of the coal in the State of Colorado is bituminous or subbituminous in rank although some anthracite is found near Crested Butte and in the Raton Mesa area. The coal in the DRCOG region is subbituminous or lignite and occurs in the coal region which is titled the Denver basin coal region. The Denver basin is defined geologically by the exposure of the basal coal bearing part of the Laramie Formation. It basically extends west to the foothills, south to Colorado Springs, north toward Greeley and eastward toward the general area of Byers. The Denver basin is asymmetrically spoon-shaped and outcrops near Byers in eastern

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[3] Communication from E. R. Landis, U.S. Geological Survey, Denver, Colorado.

[4] Ibid.

Arapahoe County with the long axis north-south and the deepest part of the basin near Denver.

In the Denver basin coal region the Laramie Formation of Cretaceous age and the younger Denver Formation of Paleocene (Early Tertiary) age are coal-bearing. The Laramie Formation is the older and deeper of the coal bearing formations and it contains subbituminous coal. The Laramie Formation outcrops around the edges of the Denver basin and may contain coal of economic potential throughout the region. However, resource studies have been largely restricted to the outcrop areas and information about the quality and quantity of coal in deeper parts of the Denver basin is limited.[5]

The coal of the Denver Formation is lignite. It is shallower and of lesser quality than the coal of the Laramie Formation. The lignite is interbedded with kaolin. Kaolin is a light clay rock which is of economic importance for use in the manufacture of porcelain and bricks, and as a source of alumina. The Bureau of Mines has estimated that more than 400 million tons of kaolin are contained in the lignite in the Denver basin. There is less information available about coal in the Denver Formation than about coal in the Laramie Formation despite the fact that the Denver Formation coals are much nearer the land surface in most of the Denver region. However, recent studies[6] indicate that the coal is unevenly distributed and that the individual coal beds tend to be lenticular.

The coals in the Laramie Formation are largely of subbituminous rank with a heat value of more than 8,300 Btu and the coals in the Denver Formation are lignitic with a heat value of less than 8,300 Btu. Analyses of coal samples prior to 1959 by the U.S. Bureau of Mines indicated that the coal in the western portions of the Denver basin is of a higher rank than that coal which crops out along the east border. In general, the coal of the west border of the basin is subbituminous B and C in rank and that of the east border is subbituminous C or lignite.[7]

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[5] Strippable Coal Resources of Colorado--Location, Tonnage, and Characteristics of Coal and Overburden, by Charles N. Speltz, U.S. Department of Interior, Bureau of Mines, Information Circular 8713, 1976.

[6] "A Preliminary Report on a Zone Containing Thick Lignite Beds - Denver Basin, Colorado," by Paul E. Soister, 1974, U.S. Geological Survey Open-File Report #74-27.

[7] Coal Resources of Colorado, Geological Survey Bulletin 1072-C, by E. R. Landis, U.S. Department of Interior, 1959.

Several studies have been completed which were useful in analyzing the coal resources of the Denver basin. However, none of the studies analyzed the same aspects of the coal resource for all areas in the region. The earliest coal study which was analyzed for use in designation of potential coal resource areas in the DRCOG region was a study prepared for the entire State of Colorado in 1959 by the U.S. Department of Interior, Geological Survey.[8] That study was a compilation and synthesis of preexisting information and included a very general mapping of coal regions within the State. It also included quantitative estimates on resources of coal in each township where the coal occurred. The data was tabulated for anthracite, bituminous and subbituminous coal. No data for lignite was included in these township size statistical analyses.

In this statewide study by the U.S.G.S., the coal resources were classified according to rank of the coal (bituminous, subbituminous, etc.) depth of the beds below the ground surface (amount of overburden), and thickness of the coal beds. The areas which appear to meet the criteria for classification as a Coal Reserve Base, that is, those areas that contain subbituminous coal at least five feet thick with less than 1,000 feet of overburden, are listed in Appendix A.

The estimates in the 1959 U.S. Geological Survey study are classified on the basis of abundance and reliability of information as "measured and indicated" original coal resources and as "inferred" original coal resources. Coal resources in the "measured and indicated" class are contained in bodies whose outer limit is generally approximately three-quarters of a mile from the outcrop or other observation point. "Inferred" resources lie a greater distance outside of "indicated and measured" resources and their outer limit is usually from one to two miles from points of observation. The distance to the outer limits of the inferred coal bodies varies because estimates of the outer limits are based largely on the surveying geologists' knowledge of the habit of the coal beds within the area under consideration and the projection of distant information into the area on the basis of geologic evidence.[9]

Several additional studies which relate to specific coalfields have been published since the 1959 statewide study. One of these studies was on the Boulder-Weld coalfield.[10] The Boulder-Weld coalfield, located in the northwest part of the Denver basin coal region, is as large as 10 miles wide and 47 miles long and covers approximately 336 square miles.[11] Coalbeds underlie the southeastern part of Boulder County, the southwest part of Weld County and a small area in the northwest corner of Adams County.

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[8] Ibid., Landis.

[9] Ibid., Landis.

[10] Analysis of the Coal Industry in Boulder-Weld Coalfield, Colorado, by Raymond L. Lowrie, U.S. Department of the Interior, Bureau of Mines, 1966, Report of Investigation 6726.

Coal mining in the Boulder-Weld field began in 1863. In the next 100 years, a total of 102.4 million tons of coal was produced.[12] Through most of the history of production in the Boulder-Weld coalfield, more coal has been produced in Weld County than in Boulder County. The principal consumer of Colorado coal is the power generating industry. The close proximity of the Boulder-Weld coalfield to the Denver metropolitan area gives it an advantage in terms of freight transportation costs in competition for the electric utility fuel market.

The rank of coal in the Boulder-Weld coalfield ranges from the higher quality subbituminous A to subbituminous B, and the coal is almost all within 1,000 feet of the ground surface. Much of the thick and easily accessible coal in the Boulder-Weld coalfield has already been mined. However, some potentially recoverable coal is still present in the field.

A more recent study of a coal deposit in this region was prepared on the lignite deposits in the plains of Adams and Arapahoe Counties near the small farming and ranching community of Watkins, Colorado. This report was prepared in 1974 by the U.S. Geological Survey (USGS).[13] The lignite lies approximately 800-1,500 feet above the subbituminous coal of the Laramie formation. The lignite zone varies from several hundred up to 500 feet thick and in a very large area it is less than 1,000 feet below the ground surface.[14] Historically, a few underground mines have operated in this lignite zone between the years 1874 and 1940. However, very little lignite was produced and most of that produced was used locally.

There are generally about three to six lignite beds that compose the lignite zone and they are often as much as 20 feet apart. Most of the beds contain partings including such materials as kaolin, other clay minerals, siltstone or sandstone. These non-coal materials usually comprise from five to 25 percent of the coalbed.[15] The lignite beds usually range from several feet in thickness to as much as 10-25 feet thick.[16] In some areas, however, the beds are as much as 50 feet thick. Some of the thicker deposits are in the area around Watkins.

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[11] Ibid., Lowrie.

[12] Ibid., Lowrie.

[13] "A Preliminary Report on A Zone Containing Thick Lignite Beds - Denver Basin, Colorado," by Paul E. Soister, 1974, U.S. Geological Survey Open-File Report #74-27.

[14] Ibid., Soister.

The lignite is not presently mined because there is not a market to make lignite economically important. However, as the subbituminous coal in this region and other areas is depleted, or as new coal processing technology develops, the importance of these lignite beds may increase significantly. Best utilization of these lignite deposits might be by gasification, insitu gasification, or liquefaction. These processes directly convert the coal into gas and liquid fuel, such as light gasoline or oils. The coal is either extracted and then processed or it is burned right in place in the ground for gasification processes. In the gasification process, coal is reacted with hydrogen under heat and pressure to produce methane. These lignite beds probably shouldn't be regarded as a supply of normal coal for typical coal burning plants. The economic attractiveness of the lignite beds might also be enhanced because of the interbedding of kaolinite. In mining the lignite beds the kaolinite could be separated to obtain two valuable mineral resources.

The most recent report on coal resources analyzed for this report is a study on the strippable coal resources of the State,[17] prepared by the U.S. Bureau of Mines in 1976. However, that study relied on some data based entirely upon geologic inference and consequently it delineates coal resources, rather than coal reserves in the State. The general criteria used in defining strippable resources in that study were a minimum coal bed thickness of two feet and a maximum overburden thickness of 150 feet except where the coal beds were thicker than two feet. Since this study identifies coal resources rather than coal reserves, these areas are designated as Potential coal resources in the Denver Region.

Coal has been designated as an environmentally significant natural resource because of its role in energy production. Coal is basically

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[15] Ibid., Solster.

[16] Ibid., Solster.

[17] Strippable Coal Resources of Colorado--Location, Tonnage, and Characteristics of Coal and Overburden, by Charles N. Speltz, U.S. Department of Interior, Bureau of Mines, Information Circular 8713, 1976.

the only energy resource in which the United States if self-sufficient. The dominance of coal among national domestic energy resources has made coal increasingly important not only as a direct source of energy but as a possible indirect energy source through processes of gasification or liquefaction.

Colorado ranks eighth among the states in demonstrated coal resource base and 15th in production.[18] The low sulfur content of the coal in Colorado and the State's central location among the Rocky Mountain States are factors which enhance the importance of this State's coal resources both now and in the future.

Coal, like petroleum and natural gas, has contributed significantly to the industrial and economic growth of the nation. However, of these three fuels, coal is the most abundant. On the basis of an adjusted and weighted analysis of available data on resources of U.S. supplies of fossil fuels in 1974, the recoverable resources of coal contain about 10 times more heat than the combined recoverable resources of petroleum and natural gas.[19]

In addition to coal's primary use as a source of heat and energy, it is a very versatile chemical raw material which is the main component of hundreds of chemical products. The steel industry uses coal for coke production. Basic coal chemicals are coal gas, light and heavy oils, and tar, and from these chemicals one can derive ammonia, benzene, resins, plastics, paints, dyes, explosives, fertilizers, nylon, drugs and many other chemical products.

It can be assumed that coal has an assured position among important fuel resources for the future. This importance is largely due to its relative abundance and widespread distribution throughout the county in addition to its chemical versatility.

Not very much coal has been produced in the Denver region in the past decade. In fact, actual coal production in the counties of Adams, Arapahoe, Denver, Boulder and Jefferson has been basically negligible in the past decade. The best mines in the Boulder-Weld coalfield in Boulder County have been pretty much mined out. However, with increasing fuel demands in the future, some of the coal resources in the Denver basin may prove to be of economic importance and significance in meeting the ever increasing energy demands of this developing region.

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[18] Ibid., Speltz.

[19] Coal Resources of the United States, January 1, 1974, Geological Survey Bulletin 1412, by Paul Averitt.

MAPPING STUDIES USED IN DESIGNATING COAL RESOURCE AREAS IN THE DENVER REGION

Map of Colorado Showing Coal-Bearing Regions and Fields, Coal Resources of Colorado, Geological Survey Bulletin 1072-C, by E. R. Landis, U.S.G.S., 1959, Scale 1" = 20 Miles.

Energy Resources Map of Colorado, by U.S. Geological Survey and Colorado Geological Survey, 1977, Scale 1:500,000.

Energy Resource Development Map of Colorado, compiled by D. Keith Murray, Colorado Geological Survey, 1976, Scale 1:500,000.

Coal Resource Map - Areas of Remaining Coal Reserves, Boulder County Land Use Department, 1976, Scale 1:36,000.

Preliminary Map Showing Lignite Zone, Denver Basin, Colorado, by Paul E. Soister, U.S. Geological Survey, 1974, Scale 1:250,000.

APPENDIX A

Prime Coal Resource Areas

Areas Designated by Township/Range
Which Meet Criteria for Classification
as Coal Reserve Base

Measured and Indicated Original Resources of
Subbituminous Coal and Lignite Greater Than 60" Thick With
0-1000 Ft. Overburden

	Reserve - Millions of Short Tons	
	Coal Bed Thickness 5-10 ft.	Coal Bed Thickness 10 ft.
Adams County		
T 1S R68W	4.62	2.15
T 3S R65W*	115.87	
Arapahoe County		
T 4S R65W*	26.30	
T 4S R66W*	43.82	
Boulder County		
T 1N R69W	14.03	0.94
T 1S R69W	33.42	28.79
T 1S R70W	86.06	
Jefferson County		
T 2S R70W	100.51	
T 3S R70W	13.30	18.26
T 4S R70W	8.76	
T 5S R69W	12.91	
T 6S R69W	.25	

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* The above tabulated deposits were listed as subbituminous coal in the data source (Geological Survey Bulletin 1072-C), however, the author did note that they might actually be lignite. Subsequent work indicates that these deposits are lignite, and more detailed information on the depth of overburden will be needed to define the Coal Reserve Base.

Source: Coal Resources of Colorado, Geological Survey Bulletin 1072-C, by E. R. Landis U.S. Department of the Interior, USGS, 1959 (Table 12).

APPENDIX B

Areas Designated as Potential Coal Resource Areas

Preliminary Map Showing Lignite Zone, Denver Basin, Colorado, Mapped by Paul Soister, U.S. Geological Survey, 1974, Scale 1:250,000.

Lignite Within 250 Feet of Surface
Lignite Within 250-1,000 Feet of Surface

Strippable Coal Resources of Colorado - as Mapped by Charles N. Speltz, U.S. Bureau of Mines, 1976.

Data shown on:

Energy Resources Map of Colorado
by U.S. Geological Survey and Colorado Geological Survey, 1977
Scale 1:500,000

Energy Resource Development Map of Colorado
by Colorado Geological Survey, 1976
Scale 1:500,000

Energy Resources Map of Colorado, U.S.G.S. and C.G.S., 1977, Scale 1:500,000.

Areas of:
Subbituminous coal with less than 3,000 feet of overburden

Environmental Geology of Boulder County, Colorado (Map Sheet #2)
Coal Resource Map - Areas of Remaining Coal Reserves in the Boulder-Weld Coalfield, Boulder County, Colorado.
by Boulder County Land Use Department, 1976
Scale 1:36,000